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The alleopathic potential of Conium Maculatum

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THE ALLELOPATHIC POTENTIAL OF CONIUM MACULATUM

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Abstract

The Allelopathic Potential of Conium maculatum

by Janet Andrew

Conium maculatum (Poison Hemlock) is a non-native member of the Umbelliferae (Apiaceae) family. The purpose of this study was to determine the allelopathic potential of Conium maculatum. Two sites were identified within the Arastradero Preserve in Palo Alto, California, with Conium maculatum present at the study site and absent from the control site. A plant inventory showed greater abundance of species at the control site. The study investigated whether early, peak standing or senescing growth had the strongest inhibitory effect on germination and growth of Bromus carinatus a native grass. The results indicate that during early growth Conium maculatum significantly inhibits germination and growth of Bromus carinatus. Peak standing growth Conium maculatum showed no effect on Bromus carinatus. Senescing Conium maculatum showed root leachate inhibited root development of seedlings. To control its spread and to prevent harm to other species during early growth, Conium maculatum should be removed completely.

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Problem Statement

The purpose of this study was to determine whether the allelopathic effect of the invasive non-native plant Conium maculatum (Poison Hemlock) is a significant mechanism in preventing or inhibiting the growth of native grass seeds and seedlings in its immediate vicinity. The study was composed of two parts, a field component and a laboratory component. The field component consisted of a plant inventory of plots, one with Conium maculatum (test plot) and one without (control plot), to identify the native plants that were present at the control plot and absent at the test plot. The second part of this study consisted of several growth experiments conducted in the laboratory to determine the positive or negative effects of Conium maculatum leachate and leaf litter on the germination and growth of the native plant species identified in the field and selected for the study.

Background

C. maculatum is an extremely invasive, non-native plant that appears to inhibit or limit the germination of seeds and the growth of a variety of plants when observed in the field; it may achieve this through allelopathy (Baskin, 1989). In particular, many native plants are out-competed by C. maculatum, which in turn has a significant impact on the overall community of plants and their herbivores (Baskin, 1989). The current study was designed to identify and demonstrate any allelopathic potential of C. maculatum. It was based in the Arastradero Preserve in Palo Alto, California, where C. maculatum has established itself and predominates in several areas. This species, originally from

Europe, exhibits highly competitive tendencies and consequently spreads rapidly, limiting the germination and growth of native species (Baskin, 1989). The central issue of this study was to document the allelopathic potential of C. maculatum, and to establish whether allelopathy contributes significantly to the low rates of germination and growth of native plants in areas where C. maculatum and the native plants coincide, or whether C. maculatum's community dominance is likely to stem from conventional resource competition alone. Allelopathy involves "the secretion by plants of chemicals such as phenolic and terpenoid compounds that inhibit the growth or reproduction of other plant species, with which they are competing" (Oxford Dictionary of Science, 1999).

Research has been undertaken to characterize the allelopathic effects of plants dating back as early as 300 B.C. (Rice, 1984) and continuing to the present day. Allelopathy is recognized as interaction between plant species. It generally falls into two categories, facilitation and interference, which refer to the positive and negative interactions, respectively (Callaway et. al. 1991). Although allelopathy was recognized almost 2000 years ago, conclusive scientific experiments have only recently been conducted (Rice, 1984).

Literature Review

Hundreds of conclusive studies have been undertaken on a variety of plants confirming the existence of allelopathy; however, none has been completed on C. maculatum (Rasmussen and Rice, 1970, Gant and Clebsch, 1975). The following literature examines the characteristics of C. maculatum, historical aspects of allelopathy and theory and methodologies necessary to determine its presence.

C. maculatum is present throughout most of the United States (Baskin, 1989). It has been described as an ideal major weed, with an ability to germinate under a variety of conditions, a condensed lifecycle, self-compatibility and high seed production. These characteristics facilitate the colonizing ability of C. maculatum (McArthy & Hanson 1998). This species prefers disturbed sites and is often found in dense clumps along the edges of waterways and roadsides. The family it belongs to, Umbelliferae (Apiaceae), is renowned for its toxicity. Toxic chemicals found in Umbelliferae are typically alkaloids. C. maculatum is no exception; coniine is present throughout the tissues of C. maculatum, with lambda coniceine additionally present during the growing season, when the fruits are still green. Coniine is a highly toxic alkaloid, and lambda coniceine is seven to eight times more toxic to humans than coniine (Fuller & McClintock 1986).

Molisch (1937) originally described allelopathy as the chemical interaction that occurs between all plant species, both positive (stimulatory) and negative (inhibitory). He also pointed out that these interactions took place amongst species throughout the whole plant kingdom, as well as amongst microbes. According to Rice (1984), allelopathy usually only refers to the detrimental effects of one plant on another due to the production of chemicals that escape into the surrounding environment. However, Rice also suggests that in addition to the harmful effects of allelopathy, the possibility of stimulatory effects should not be excluded from the literature. "Apparently most, if not all organic compounds that are inhibitory at some concentrations are stimulatory to the same processes in very small concentrations" (Rice 1984). Rice went further to define allelopathy, "as any direct or indirect (harmful or beneficial) effect of a plant, including microbes, on another plant through release of chemicals that escape into the environment" (1984).

The original concept of allelopathy actually dates back to as early as 300 B.C. when Theophrastus, an avid botanist of the time, observed that certain legumes did not 'reinvigorate' the soil as others did and that, instead, the soil became exhausted (Rice 1984). During the nineteenth century, a French botanist named De Candolle suggested that crop rotation could be the answer to poor, exhausted soils depleted by crop-plant exudates (Rice 1984). It is apparent that humans have been aware of the allelopathic effects of certain plants for over 2000 years, yet only in the last century have controlled scientific experiments been conducted (Rice 1984).

Modes of Action

Although allelopathy may inhibit seed germination, much research suggests that seed germination is not the primary response to allelopathy (Williams and Hoagland, 1982). Chaves and Escudero (1997) suggest that in some species, allelochemicals may not directly inhibit germination, but instead they appear to cause a reduction in the size of cotyledons and roots, which in turn could hinder further growth of the seedling. Mahall and Callaway (1992) observed that inhibition in two Mojave Desert shrubs took place predominantly through root communication; the presence of allelochemicals caused the two shrubs in question to become spatially exclusive (1992). The root communication mechanism involved the "release of a readily diffusible, generally inhibitory substance by Larrea roots into the soil, rather than a simple depletion of water or nutrients..." (Mahall & Callaway, 1992). Durrett and Levin (1997) observed a similar occurrence with bacteria colonies and attributed this behavior to the structured environment of the bacteria. "The evolution of allelopathy is possible only in a structured environment".

Distribution of Allelochemicals

Chemicals with allelopathic potential may be present in most plant tissues including, flowers, fruits, leaves, stems, seeds, and rhizomes (Putnam & Tang, 1986). However, these chemicals may never be released during the normal life cycle of the plant. In addition, chemicals are released at different periods during the plant lifecycle. Bokhari (1978) found that plant material collected during senescing appeared to inhibit less than that collected during early growth and peak growth. In this case, fallen leaves release chemicals that significantly inhibit growth of seeds or dormant vegetation, as well as leaching or microbial activity (Gant & Clebsch, 1975). In addition to the age of various plant parts, the season may have an influence on the relative amounts of toxins released. For instance, the greatest quantity of essential oils can be extracted from Artemisia campestris, a known allelopath, in the fall (Halligan 1975). Gant and Clebsch (1975) considered each of the three phenological stages of the Sassafras albidum life cycle when determining the species and number of plants affected by it; they also found that large areas were affected by the Sassafras stands.

Indirect Allelopathy

Allelochemicals may act alone on the under-story community and surrounding area, or in combination with one or more factors such as depletion of nutrients, lighting, moisture content of the soil, nitrogen depletion and mycorrhizal activity (Yun & Maun, 1997). In addition to the direct interference caused by allelopathic chemicals on seed germination and growth, toxins damaging the mycorrhizal associations between roots and fungi may bring about indirect effects. Mycorrhizal associations help plants reach minerals or compounds that would otherwise be out of reach by means of an extensive system of hyphae. Certain chemicals extracted from the coastal species Artemisia campestris significantly inhibit mycorrhizal colonization, which in turn leads to growth inhibition of several sand-dune species (Yun & Maun, 1997). Other studies show that lack of endo-mycorrhizal activity can reduce phosphorus uptake specifically in hardwood seedlings and therefore limit growth (Tobiessen and Werner, 1980). This study concluded that the most plausible explanation for the lack of endo-mycorrhizal activity was allelochemical suppression (Tobiessen and Werner, 1980). However, other studies have found that some chemicals have a stimulatory effect on mycorrhizae (Yun and Maun, 1997).

Methods for Studying Allelopathy

Chaves and Escudero (1997) used a comparison between two neighboring plots of Cistus ladanifer, one with a complete absence of Cistus ladanifer, and the other dominated by it. They collected data on the number of species present and absent in the test area. Allelopathy does not occur in isolation, and many other factors have to be considered. These factors include the absence of viable seeds that could potentially colonize an area, herbivory, and soils low in moisture and nutrients (Swank and Oechel, 1991). Only when important variables have been accounted for, can any one factor be isolated. For example, Callaway et al. (1991) took into consideration temperature, fine tree root distributions and light or shade. They suggest that "the overall effect of one species on another may be dependent on physical factors and the combination of competition for different resources...". Gentle and Duggin (1997) highlight how difficult it is to distinguish allelochemicals from interactions promoted by density-dependent resource competition.

Many laboratory bioassays provide convincing evidence for the presence of allelopathy (Rice, 1984), yet under field conditions few have established its operation (Putnam and Weston, 1986). In fact, most laboratory studies show very little if any correspondence to field conditions (Inderjit & Dakshini, 1995).

Laboratory Experiments

Throughout the last century, many techniques have been explored in order to demonstrate the allelopathic effects of certain plants. Inderjit and Dakshini (1995) put together a comprehensive paper reviewing the various methodologies available; within it, they discuss the various pitfalls to be avoided and the most effective methods to use. One mistake they highlight refers to the collection of allelochemicals from the various plant structures. However, Inderjit and Dakshini recommend avoiding this practice, as additional chemicals other than allelochemicals can be released using this technique, thus contaminating the data. Much of the literature pertaining to allelopathy uses maceration or grinding to extract chemicals from the plant. One such study involves the allelopathic potential of the weed Alliaria petiolata, where plant material was separated into above and below ground portions; 1kg each of roots and shoots were macerated and then diluted with distilled water (Mcarthy and Hanson, 1998). Whitehead et al. (1981) suggested the use of water to extract chemicals, by simply immersing or spraying the relevant plant parts and then collecting the washings or leachate. Allelochemicals present in plants in the field are more than likely released due to their solubility in water, therefore using any other substance to extract them would be of little ecological significance or experimental value (McPherson and Muller, 1969, Del Moral and Muller, 1970).

Many studies use ground leaves, stems, roots, or leaf-litter to test for the allelopathic potential of a particular species; however, Inderjit and Dakshini (1995) recommend avoiding this practice, as additional chemicals other than allelochemicals can be released using this technique, thus contaminating the data. They suggest that experiments should be conducted in a way that most closely simulates field conditions. Therefore, in order to test for allelopathy, the actual plant tissue purported to contain the allelochemicals should be added to the surrounding soil, perhaps in the form of leaf litter (Inderjit & Dakshini 1995). Many other techniques for extracting the allelochemicals have also been explored, and some techniques are more accurate than others. For example, Gant and Clebsch (1975) used several methods for collecting allelochemicals that corresponded to the good practices advocated by Inderjit and Dakshini; one such method was the collection of canopy wash by spraying distilled water over a stand of Sassafras. The age of various plant parts used for bioassays is also argued to be of great importance to the accuracy of the results. Many plants produce different and varied amounts of chemicals throughout their lifecycles and during the different seasons; this fact is of the utmost importance when collecting chemicals (Gant & Cesch, 1975). Inderjit and Dakshini (1995) also recommend avoiding the use of seed germination as the only gauge for growth response.

Objectives

The overall objectives of this research were to identify the plant species affected by C. maculatum in the field, determine whether C. maculatum inhibited the germination and/or growth of seeds and seedlings of these plants under laboratory conditions, and to identify the mechanism by which any inhibitor functions. In particular, this study investigates whether early, mid-season, or late C. maculatum growth has the strongest inhibitory effect on another member of the plant community, Bromus carinatus (California Brome Grass). It also examines the effect of root versus leaf and shoot leachate and the effect of leachate versus leaf litter on the Bromus carinatus. This study is based upon field observations, which it attempts to corroborate through laboratory experiments.

Hypotheses

Field Component

Plant species whose populations are negatively correlated with the presence C. maculatum in the field will exhibit allelopathic response to C. maculatum extracts and litter in the laboratory.

Laboratory Component

C. maculatum exhibits notable phenological changes throughout the season. For this reason, laboratory studies have been separated into effects of early, peak and late season C. maculatum on the associated native grass species.

A –During Early Growth

Early growth C. maculatum is bright green with delicate finely cut fern-like leaves. Young plants are lower in stature with shorter stems and fewer purple spots than more mature plants (Linn, 1993).

H_o A 1) There is no significant difference in shoot and root length between native grass seedlings watered with early growth C. maculatum *root* leachate and those watered with distilled water under normal light conditions.

H_o A 2) There is no significant difference in shoot and root length between native grass seedlings watered with early growth C. maculatum *leaf and stem* leachate and those watered with distilled water under normal light conditions.

H_o A 3) There is no significant difference in shoot and root length between native grass seedlings grown with early growth C. maculatum *leaf litter* placed on top of the soil and those grown without C. maculatum *leaf litter* on top of the soil under normal light conditions.

B – During Peak Standing Growth

During peak standing growth, C. maculatum elongates (~ 1m), producing erect, branched, hairless stems with purple spots. Its foliage loses its delicate structure and bright green color, becoming tougher and darker green with a musty-scented odor. The plant develops compound umbels that may be terminal or lateral with whitish flowers. The plants lower leaves may become yellowish (Linn, 1993).

H_o B 1) There is no significant difference in shoot and root length between native grass seedlings watered with peak standing growth C. maculatum *root* leachate and those watered with distilled water under normal light conditions.

H_o B 2) There is no significant difference in shoot and root length between native grass seedlings watered with peak standing growth C. maculatum *leaf and* *stem* leachate and those watered with distilled under normal light conditions.

H_o B 3) There is no significant difference in shoot and root length between native grass seedlings grown with peak standing growth C. maculatum *leaf litter* placed on top of the soil and those grown without C. maculatum *leaf litter* on top of the soil under normal light conditions.

C –During Senescence

C. maculatum foliage begins to turn yellow during senescence becoming straw-like in texture. Globular fruits develop and ripen to form slightly compressed ribbed seeds (Linn, 1993).

H_o C 1) There is no significant difference in shoot and root length between native grass seedlings watered with senescing C. maculatum *root* leachate and those watered with distilled water under normal light conditions.

H_o C 2) There is no significant difference in shoot and root length between native grass seedlings watered with senescing C. maculatum *leaf and stem* leachate and those watered with distilled water under normal light conditions.

H_o C 3) There is no significant difference in shoot and root length between native grass seedlings grown with senescing C. maculatum *leaf litter* placed on top of the soil and those grown without C. maculatum *leaf litter* on top of the soil under normal light conditions.

Methods and Results

The study design was split into two phases: field observational study and a laboratory based experiment.

Study Site

The study site selected is in Arastradero Preserve near Highway 280 in Palo Alto, California, approximately 2 miles west of Alpine Road (Figure 1). The preserve is within the California Floristic Province in the plant region known as Coast Mountain Ranges (Linn W. 1993). Within this region are a number of plant-community zones related to the climate and altitude in that particular area. Arastradero Preserve within the South Coast Ranges experiences a Mediterranean climate, with hot, dry summers and mild, wet winters. An oak woodland community interspersed with grassland characterizes the gently rolling hills (Niehaus & Ripper 1976). There are many trails and several roads throughout the preserve that allow plants like C. maculatum, which gains a foothold in disturbed sites, to spread rapidly. C. maculatum at the preserve has remained relatively undisturbed for several years, allowing it to invade the area and become established, forming dense thickets.

Field Study

Methods

Study Design

The field-based study analyzed a ~30m^2 test plot where C. maculatum was present and a similar sized control plot where C. maculatum was not present. Only one C. maculatum study plot and one control plot were measured due to the time constraints involved with assessing more than 2 plots. The control plot was chosen because it was located at the same distance from the stream as the test plot, with the same soil conditions, gradient and exposure, but it lacked C. maculatum.

Data Collection

A plant inventory was compiled for both plots, to provide information on the variety and abundance of species present at the plot where C. maculatum was not present (control plot) in comparison to the plot where the species was present (test plot). At each plot, 10 quadrats were measured for plant species number and abundance by counting individual plants. The quadrats were 2 m^2 (Bonham, 1937) to measure grasses and small shrubby plants. A completely randomized design (Hurlbert, 1984) was used to assign the 10 quadrats at each plot.

Results

The results from the plant inventory were compared visually to determine which plants were present and which were absent at the plot with C. maculatum. The plant inventory (Table 1) showed a clear distinction between the plants present at the plot with C. maculatum in comparison to the plot without C. maculatum. There was a greater variety and abundance of plants at the plot without C. maculatum with 5 grass species and 10 forbs present in comparison to the plot with C. maculatum with only 5 forb species present. Brassica rapa, Carduus pycnocephalus, Convolvulus arvensis and Picris echioides appear to be unaffected by the presence of C. maculatum. Most obviously, several native grass species were only present at the plot without C. maculatum indicating that their germination and growth may have been inhibited by the presence of C. maculatum. Because the study was un-replicated, of course random chance may simply explain this problem. The fact that Q. lobata was present at the plot with C. maculatum may confound the results.

Table 1 - Plant Inventory

		Plot One		Plot Two	
Latin Name	**Common Name**	**# Quadrats**	**Total #**	**# Quadrats**	**Total #**
Avena fatua	Wild Oat	10	Throughout	-	-
Brassica rapa	Field Mustard	3	19	3	16
Bromus carinatus	California Brome	10	Throughout	-	-
Carduus pycnocephalus	Italian Thistle	4	8	2	2
Conium maculatum	Poison Hemlock	-	-	10	throughout
Convolvulus arvensis	Bindweed	3	74	1	1
Dipsacus fullonum	Wild Teasel	1	1	-	-
Elymus elymoides	Squirreltail	10	Throughout	-	-
Elymus glaucus	Blue Wild Rye	10	Throughout	-	-
Juncus patens	Rush	1	1	-	-
Nassella pulchra	Purple Needle Grass	10	Throughout	-	-
Picris echioides	Bristly-ox-tongue	8	75	4	31
Plantago lancealata	English Plantain	1	3	-	-
Quercus lobata	Valley Oak	-	-	1	1
Rumex crispus	Curly Dock	3	63	-	-
Silybum marianum	Milk Thistle	1	4	-	-
Verbena californica	California Vervain	1	1	-	-

Laboratory Study - Germination Trials

Methods

Experimental Design

Preliminary germination trials were conducted using 4 species of grass seeds identified at the control plot that were not present at the plot with C. maculatum (Table 1). Four seed trays, one for each species (Nassella pulchra, Elymus glauca, Bromus carinatus and Elymus elymoides) were planted in sterilized soil with thirty seeds per tray. After 20 days growing outside, the seedlings were counted and those seeds that did not germinate were observed and then discarded along with the other seedlings that did germinate.

Results

As a result of these preliminary trials B. carinatus was chosen for the replicated laboratory experiment because it had a 100% germination rate after 20 days. The other grass seeds included in these trials had much lower rates of germination (Table 2).

Table 2 – Preliminary Germination Results

Grass Seed Type	Germination %	Germination #
Nassella pulchra (Purple Needle Grass)	86.67%	26/30
Elymus glauca (Blue Wild Rye)	66.67%	20/30
Bromus carinatus (California Brome Grass)	100%	30/30
Elymus elymoides (Squirreltail)	80%	24/30

Laboratory Study - Allelopathy Experiments

Methods

Experimental Design

In some cases alellochemicals are only released into the substratum after the plant reaches a particular growth phase (Inderjit and Dakshini, 1995). The particular growth phase in which the majority of chemicals were released from C. maculatum was unclear. In order to ascertain this, exudates and leachates were collected throughout the three phases of growth, early, peak standing and senescence. Equally importantly, as opposed to simply measuring the rate of germination of the B. carinatus seedlings to determine the inhibitory or stimulatory effect of C. maculatum, the more sensitive parameters of root and shoot length were measured (Wink & Twardowski 1992).

The germination and growth responses of B. carinatus to leaf and stem leachate, root leachate and leaf litter of C. maculatum were measured during the three phenological stages of the C. maculatum life cycle. The seeds were grown outside under normal light conditions in sterilized soil using similar procedures to Davidson & Barbour (1977), which eliminated any additional variables present in soil from the field, such as a build-up of allelochemicals. They were equally watered with distilled water (control) or leachate (treatment) respectively when necessary (Rasmussen & Rice, 1970). The moisture content of the soil surface was used to determine how much liquid the seedlings required. If one seed tray required water or leachate, all seed trays received the same quantity of liquid. In a third treatment, C. maculatum leaf litter was collected every 2 days and placed on the surface of the trays to a depth approximately the same as that experienced in the field. Leaf litter was collected during each phenological stage of the plant life cycle. A control was also prepared for each treatment, where the grass seeds were grown but were not treated with leachate or leaf litter, rather they were simply watered with distilled water. Thirty B. carinatus seeds were planted per tray, with 5 trays for each treatment, totaling 150 seeds per treatment (Figure 2). Unfortunately, after the experiments were completed, it was observed that the spatial layout of the treatments led to a problem with pseudo-replication.

Leachate Preparation

C. maculatum foliage was gathered in the field every 2 days and transported back to the laboratory environment, where leachates were prepared using 100g of C. maculatum material soaked in 250 ml of distilled water for 48 hours (Bokhari, 1978). Inderjit and Dakshini (1995) recommend soaking the relevant plant material in distilled water as this most accurately simulates field conditions. Using distilled water eliminated the potential effect of other compounds that may have been present in natural water runoff under field conditions. To ensure that the 3 phenological stages of the plant life cycle were encompassed, leachates were prepared throughout early growth, peak growth and senescence (Bokhari, 1978). During the lab-based experiments 5 seed trays were used for each of the 3 experiments in each batch (Figure 2).

Three experiments were conducted under the following conditions:

Experiment 1. Effects of early growth C. maculatum foliage on B. carinatus.

Experiment 2. Effects of peak standing growth C. maculatum foliage on B. carinatus.

Experiment 3. Effects of senescing C. maculatum foliage on B. carinatus.

Each of the experiments included the following treatments:

Treatment 1 - B. carinatus seeds were grown in the study environment and watered with leachate prepared from C. maculatum roots.

Treatment 2 - B. carinatus seeds were grown in the study environment and watered with leachate prepared from C. maculatum leaves and stems.

Treatment 3 - B. carinatus seeds were grown in the study environment and covered with C. maculatum leaf and stem material.

Control - B. carinatus seeds were grown in the study environment and watered with distilled water.

Data Collection

The following data were collected for each treatment after 20 days:

- number of seeds germinated
- length of seedling roots
- length of seedling shoots

At the end of the experiments (approximately 20 days), when the control seedlings had emerged, the grass seedlings were carefully removed from the seed trays and shoot and root lengths were measured using a ruler. The seedlings were laid flat and the shoots and roots pulled taut in order to measure the full length of both.

Statistical Analysis

The data from the lab-based experiments on the number of seeds that germinated and the growth rates and health of the seedlings collected from both the study group and the control group were subjected to statistical analysis using SPSS (Statistical Package for the Social Sciences) version 10 for Windows. The general linear model was MANOVA (Appendix 1), which was used to determine the effect of the various treatments (leachate from root and shoot and leaf litter) and the different growth phases (early growth, peak standing and senescence) in addition to an interaction between treatment and growth phase combined on the germination and health of the native grass seeds and seedlings respectively. The data was also subjected to ANOVA (Appendix 2) and a Chi square analysis (Appendix 5). Some previous authors have used only a simple t-test to compare root and shoot length under various treatments (McCarthy & Hanson 1998; Yun & Maun 1997; Petranka & McPherson 1979; Inderjit 1998), but ANOVA was used in the majority of studies done previously (Mahall & Callaway 1992; Swank &

Oechel 1991; Callaway et al. 1991; Gentle & Duggin 1997; McCarthy & Hanson 1998; Yun & Maun 1997). The results of this two-way analysis were used to support or reject the hypotheses.

Results

The data was subjected to MANOVA (Appendix 1), which showed that the independent variables (treatment, phase and treatment and phase combined) had an effect on the dependent variable (B. carinatus) ($p < 0.001$). ANOVA (Appendix 2) was used to focus the data obtained from MANOVA on the most significant results and further strengthened the fact that the chemicals released by C. maculatum during early growth had the most significant impact on germination and growth of the native grass seeds and seedlings respectively ($p < 0.001$). Lastly, a Chi square analysis (Appendix 5) revealed a strong correlation between germination, treatment and growth phase ($p < 0.005$). Different treatments had different effects during the various growth phases. The overall effect of the tests appeared to be driven by the early growth phase and senescence phase of C. maculatum. The fact that peak standing growth C. maculatum had no effect on the grass seeds and seedlings was masked by the other two phases in the statistical analysis (treatment*phase $p < 0.001$) but became clear from the graphs.

Experiment 1 – Early Growth C. maculatum

Each of the graphs shows a very similar trend during early growth, with root leachate and shoot and stem leachate having a marked effect on germination of B.

carinatus seeds and shoot and root length of the seedlings (Figure 3). Leaf litter still had an effect on the seeds and seedlings in comparison to the control but to a lesser extent. B. carinatus seeds exposed to early growth C. maculatum leachates were significantly inhibited in growth and development ($p < 0.001$). Seed germination, shoot growth and root growth were all inhibited by both of the C. maculatum leachates.

Effects of Root Leachate

In seedlings exposed to early season C. maculatum root leachate (treatment 1), the mean root length was 4.83 cm less than that of the control and the mean shoot length was 5.97 cm less than that of the control. The results show that root leachate had a significant impact on the seedlings during the early growth phase of the C. maculatum life cycle. Both root and shoot length were significantly lower than root and shoot length in the control. The percentage of seeds to actually germinate (31%) was considerably lower than that of the control (97%).

Effects of Shoot and Stem Leachate

Seedlings treated with C. maculatum shoot leachate (treatment 2) had mean root length that was 4.81 cm less than that of the control, and mean shoot length of 5.97 cm less than that of the control. The results show that shoot and stem leachate had a significant impact on the seedlings during the early growth phase of the C. maculatum life cycle. Both root and shoot length were significantly lower than root and shoot length in the control. The percentage of seeds to actually germinate (34%) was considerably lower than that of the control (97%).

Effects of Leaf Litter

Seedlings treated with C. maculatum leaf litter had a mean root length that was 3.06 cm less than that of the control and a mean shoot length was 3.74 cm less than that of the control. The results show that leaf litter (treatment 3) had a significant impact on the seedlings during the early growth phase of the C. maculatum life cycle. Both root and shoot length were significantly lower than root and shoot length in the control. The percentage of seeds to actually germinate (76%) was considerably higher than for the other treatments but still lower than that of the control (97%).

Table 3 – Early Growth Results of Null Hypotheses

Hypothesis	**Outcome**
H_o A 1) There is no significant difference in shoot and root length between native grass seedlings watered with early growth C. maculatum *root* leachate and those watered with distilled water under normal light conditions.	Null Hypothesis Rejected
H_o A 2) There is no significant difference in shoot and root length between native grass seedlings watered with early growth C. maculatum *leaf and stem* leachate and those watered with distilled water under normal light conditions.	Null Hypothesis Rejected
H_o A 3) There is no significant difference in shoot and root length between native grass seedlings grown with early growth C. maculatum *leaf litter* placed on top of the soil and those grown without C. maculatum *leaf litter* on top of the soil under normal light conditions.	Null Hypothesis Rejected

Experiment 2 – Peak Standing Growth C. maculatum

B. carinatus seeds exposed to peak standing growth C. maculatum were not significantly inhibited in growth and development. Seed germination, shoot growth and root growth were not inhibited by either of the C. maculatum leachates, or by leaf litter (Figure 4).

Effects of Root Leachate

In seedlings treated with C. maculatum root leachate (treatment 1), there was no significant difference between the root and shoot means in comparison to the control. There was no significant difference between the percentage of seeds that germinated when treated with root leachate to that of the control, 93% and 94% respectively.

Effects of Shoot and Stem Leachate

For seedlings treated with shoot and stem leachate (treatment 2), there was very little difference between the root and shoot means in comparison to the control. The percentage of seeds that germinated during peak standing growth (94%) was the same as that of the control.

Effects of Leaf Litter

Seedlings treated with leaf litter (treatment 3) showed little difference between the root and shoot means compared to the control; once again, there was no significant difference. The percentage of seeds that germinated during peak standing growth (89%) was close to that of the control (94%).

Table 4 – Peak Standing Growth Results of Null Hypotheses

Hypothesis	**Outcome**
H_0 B 1) There is no significant difference in shoot and root length between native grass seedlings watered with peak standing growth C. maculatum *root* leachate and those watered with distilled water under normal light conditions.	Null Hypothesis Supported
H_0 B 2) There is no significant difference in shoot and root length between native grass seedlings watered with peak standing growth C. maculatum *leaf and stem* leachate and those watered with distilled under normal light conditions.	Null Hypothesis Supported
H_0 B 3) There is no significant difference in shoot and root length between native grass seedlings grown with peak standing growth C. maculatum *leaf litter* placed on top of the soil and those grown without C. maculatum *leaf litter* on top of the soil under normal light conditions.	Null Hypothesis Supported

Experiment 3 – Senescing C. maculatum

Senescing C. maculatum growth appears to have little or no effect on the germination and growth of B. carinatus seeds and seedlings respectively with the exception of C. maculatum root leachate, which appears to inhibit B. carinatus root development. The other treatments have less of an effect on root development. Seed germination showed an effect of senescing C. maculatum shoot and root leachate, as well as leaf litter. Shoot growth, as with germination, showed some effects, particularly from the C. maculatum root leachate. Senescing C. maculatum shoot leachate inhibits root development, but the other treatments have less of an effect (Figure 5).

Effects of Root Leachate

For seeds and seedlings treated with C. maculatum root leachate, the mean root length was 2.41 cm less than that of the control and the mean shoot length was 3.32 cm less than that of the control. The percentage of seeds to germinate when treated with root leachate was considerably lower than that of the control, 68% and 98% respectively.

Effects of Shoot and Stem Leachate

Shoot and stem leachate had an effect on the mean root length, which was 3.96 cm less than that of the control and the mean shoot length was 2.77 cm less than that of the control. The percentage of seeds to germinate was lower than that of the control, 77% and 98% respectively.

Effects of Leaf Litter

Seeds and seedlings treated with leaf litter had a mean root length that was 0.52 cm less than that of the control and the mean shoot length that was 1.35 cm less than that of the control. The percentage of seeds to germinate when treated with leaf litter was close to that of the control, 81% and 98% respectively.

Table 5 – Senescence Results of Null Hypotheses

Hypothesis	**Outcome**
H_o C 1) There is no significant difference in shoot and root length between native grass seedlings watered with senescing C. maculatum *root* leachate and those watered with distilled water under normal light conditions.	Null Hypothesis Rejected
H_o C 2) There is no significant difference in shoot and root length between native grass seedlings watered with senescing C. maculatum *leaf and stem* leachate and those watered with distilled water under normal light conditions.	Null Hypothesis Rejected
H_o C 3) There is no significant difference in shoot and root length between native grass seedlings grown with senescing C. maculatum *leaf litter* placed on top of the soil and those grown without C. maculatum *leaf litter* on top of the soil under normal light conditions.	Null Hypothesis Supported

The allelochemicals produced by C. maculatum, found in root leachate, shoot and stem leachate and leaf litter follow a seasonal pattern. Early growth C. maculatum and senescing C. maculatum growth produce the majority of chemicals that had a marked effect on B. carinatus. However, peak-standing growth C. maculatum had no significant effect on B. carinatus.

Discussion

Experiment 1 – Early Growth C. maculatum

The results illustrated by the graphs would suggest that the majority of chemicals produced by C. maculatum are released during the early phase of growth. It would appear that root leachate and shoot and stem leachate had the most marked effect on the

B. carinatus seedlings, severely limiting germination and then inhibiting the growth of roots and shoots. Without an adequate root system, the seedlings would be much less effective and poor competitors to the C. maculatum seedlings, which could quickly become established and limit any subsequent chance of competition from other species. The results indicate that the majority of chemicals are produced during the early phase of the C. maculatum life cycle, from roots, shoots and stems and from fallen leaf litter. In relation to management and control of the species and its impact on other forbs and grasses, it is clear that the whole plant needs to be removed including roots, leaves and stems and any leaf litter that may have fallen onto the ground surface. Soon after germination, the young C. maculatum plants are quite delicate, have yet to develop an extensive root system and can be easily removed. Ideally, native grass plugs should be planted at this time of year, once the C. maculatum has been removed in its entirety. If seeds are used instead of plugs, it may be a good idea to double or triple the number of seeds sown in order to compensate for the low rate of germination experienced in the laboratory.

Experiment 2 – Peak Standing Growth C. maculatum

During peak standing growth the germination rates for each of the treatments is close to or the same as that of the control, which suggests that the treatments had no effect on the germination of B. carinatus. A similar trend can be observed in the graphs for shoot and root length with even a slight tendency to increase as a result of leaf litter treatment. This slight increase in shoot length when compared to the control may be due to the leaf litter affording the seedlings some shade during the hottest part of the growing season and causing a slight cooling effect or indeed a micro-climate. The seedlings observed in the laboratory appeared to be striving to reach light perhaps due to the shading from the leaf litter in comparison to the seedlings subjected to the other treatments. From the graphs, it appears unlikely that the chemicals produced by C. maculatum during peak standing growth have any stimulatory effect on the B. carinatus seeds and seedlings. C. maculatum appears to produce no chemicals during peak standing growth, which could be due to the fact that all of its resources are devoted to producing flowers followed by fruits at this time. Native grass plugs could possibly be planted during this growth phase; however, this is the hottest part of the season, which could prove problematic for the grasses by inhibiting root growth and development. C. maculatum flower heads (umbels) should be removed as soon as possible to prevent the fruits from ripening, therefore increasing the seed bank. Peak standing growth would be the best time to remove the umbels or senescence at the latest.

Experiment 3 – Senescing C. maculatum

During senescence, the germination rates for each of the treatments are close to that of the control, which suggests that the treatments had little or no effect on the germination of B. carinatus. Shoot lengths appear to be affected to a small extent by senescing C. maculatum growth, which could be a result of the plant dieing back and starting to decompose, releasing chemicals back into the soil. Most noticeably however, is the impact of both leachates especially shoot leachate, on B. carinatus root development. This marked effect may be a result of C. maculatum producing increased amounts of chemicals as a competitive strategy in order to prevent other species from gaining a foothold and developing extensive root systems that would interfere with the nutrients and moisture available for the next season's newly germinated C. maculatum seedlings. Any remaining plants and leaf litter that were not removed earlier in the year should be removed now. This will prevent any further chemicals leaching into the soil and limit the number of C. maculatum seeds adding to the seed bank already present.

Limitations

The fact that only two plots were studied in the field study, a study plot and a control plot meant that results from the field component were applicable only to those conditions. Further plots may be needed to generalize about C. maculatum's effect on native plants. In addition, using correlation rather than a manipulative study for fieldwork results in the confusion of covariation with causation. Care was taken in the experimental design; controlled laboratory experiments were conducted to ensure repeatability. However, the lack of randomization in the layout of the seeds and seed trays in the laboratory led to a problem with pseudo-replication. The results obtained are probably robust, but there is a chance that effects result from some spatial gradient due to pseudo-replication as opposed to the treatments applied. The laboratory results showed that the factors tested contribute significantly to allelopathic effects in the laboratory. Careful techniques were used for the laboratory experiments to eliminate confounding factors and more clearly show the effect of C. maculatum on the B. carinatus grass seeds and seedlings being tested.

Conclusion

Management Recommendations

The results from the research suggest that C. maculatum needs to be removed in its entirety, which includes roots, shoots and stems and any fallen leaf litter. This is necessary because chemicals are produced throughout the plant. The most effective time to commence management of C. maculatum is during the early growth phase shortly after germination when the plants are young with only shallow roots. Any plants left in the field during peak standing growth or senescence should be removed before the fruits ripen forming seeds along with any remaining leaf litter.

Native grass plugs should be planted during early growth once the C. maculatum has been removed. If grass seeds are sown, double or triple the quantity could be used to compensate for the low rates of germination experienced under laboratory conditions and the fact that leachates may persist in the soil long after the C. maculatum plants have been removed.

Recommendations for Further Research

No attempt was made to identify or isolate the actual allelochemicals produced in the leachates collected from C. maculatum; however, further research would be useful to identify the actual chemicals at work and the nature of the compounds involved, now that the growth phase during which most chemicals are active on B. carinatus has been identified. Similar studies could attempt to demonstrate the effect of the chemicals produced by C. maculatum on other non-native species and use this information to develop herbicides to control plant populations as opposed to the use of pesticides. In addition, it may be useful to know whether the chemicals produced by C. maculatum actually prevent the plant species growing within close proximity to C. maculatum from absorbing nutrients from the soil or if some other mechanism is involved.

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Figure 1 - Map of Study Site

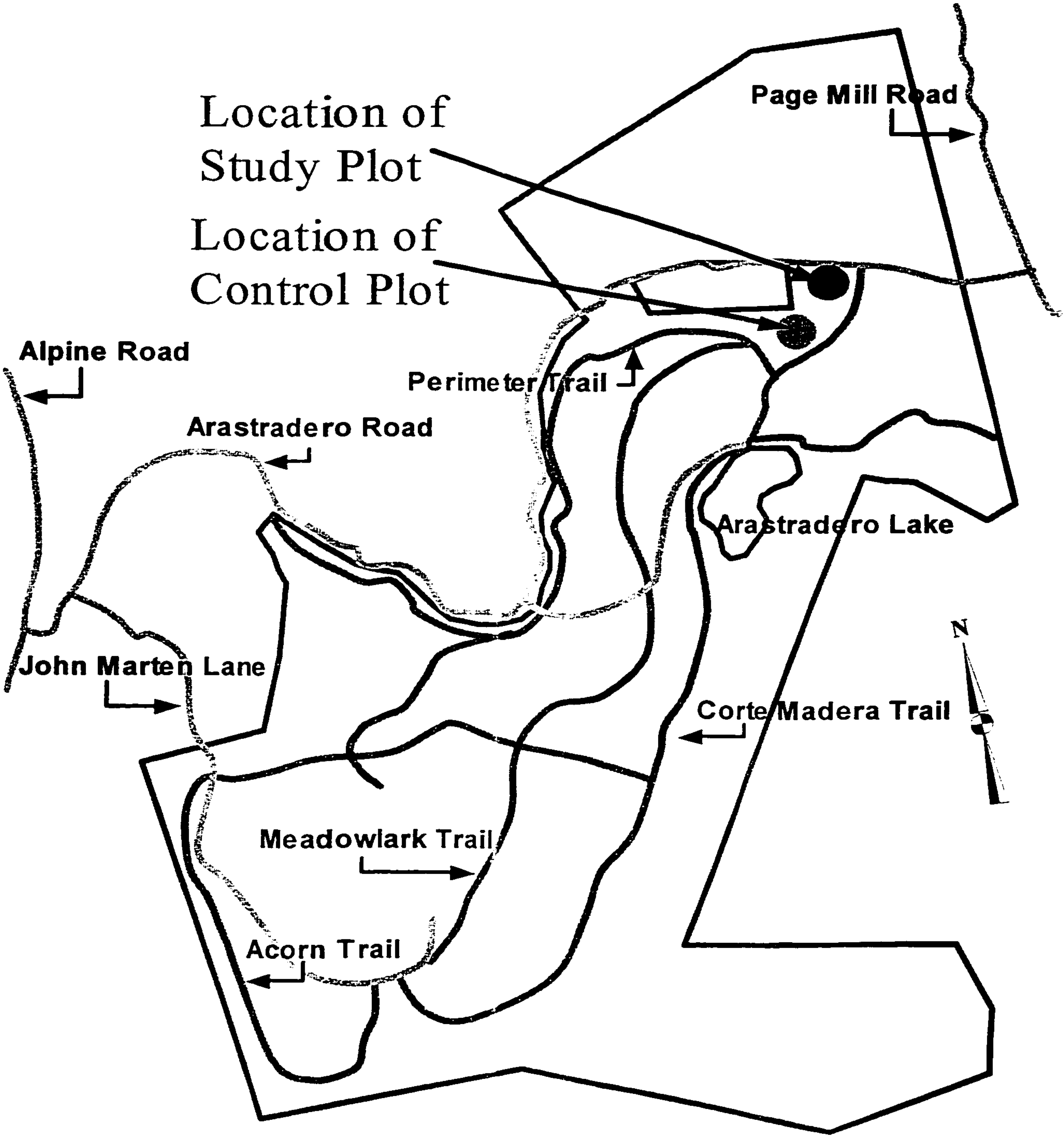
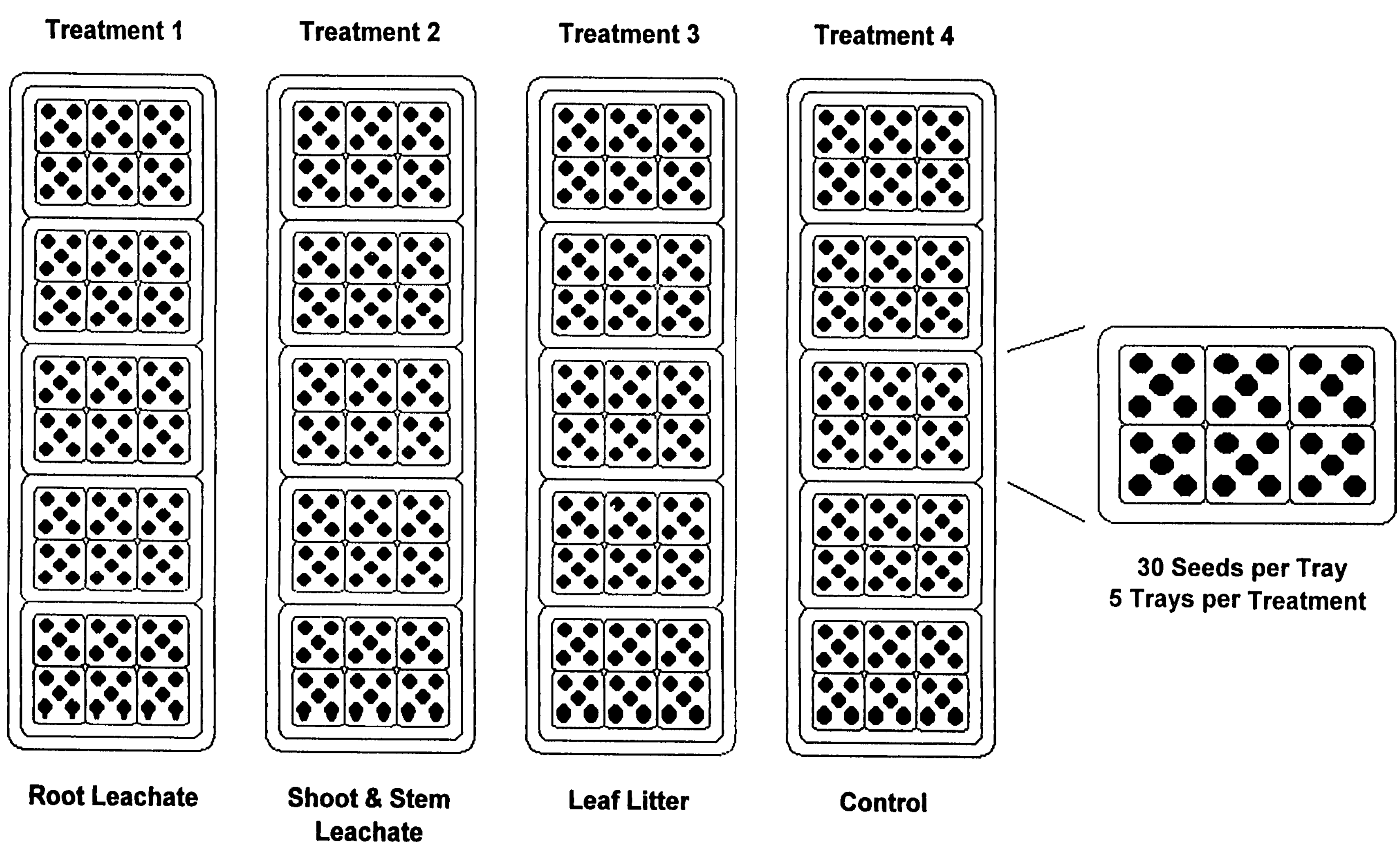


Figure 2 – Laboratory Diagram

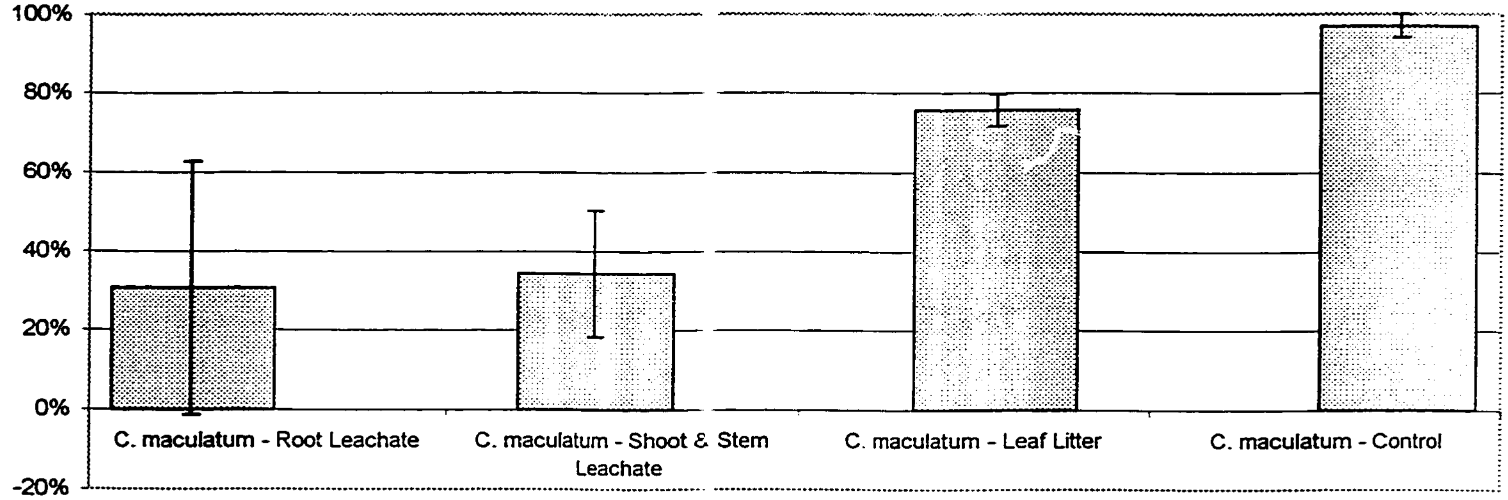


Repeated for each Growth Phase (Early, Peak Standing, and Senescence)

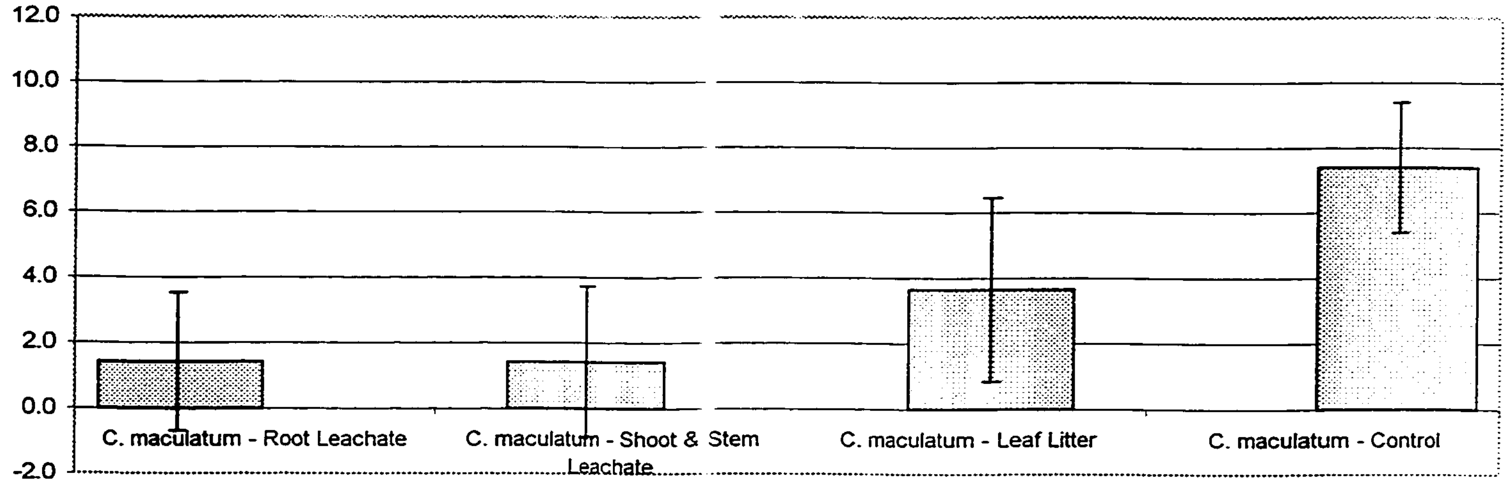
Figure 3 - Early Growth Phase

Seed germination, shoot growth and root growth were all inhibited by both of the C. maculatum leachates and to a lesser extent leaf litter

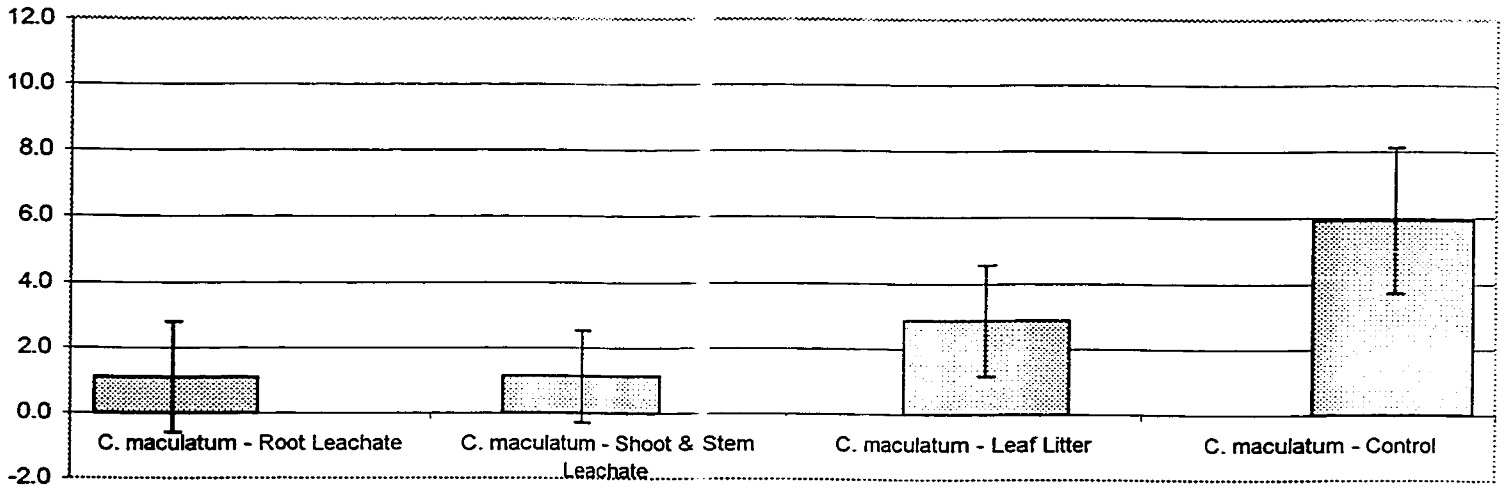
Germination Rates - % of Seeds of B. carinatus Germinating per Treatment



Summary of Means of B. carinatus Shoot Lengths (cm) after 20 dyas



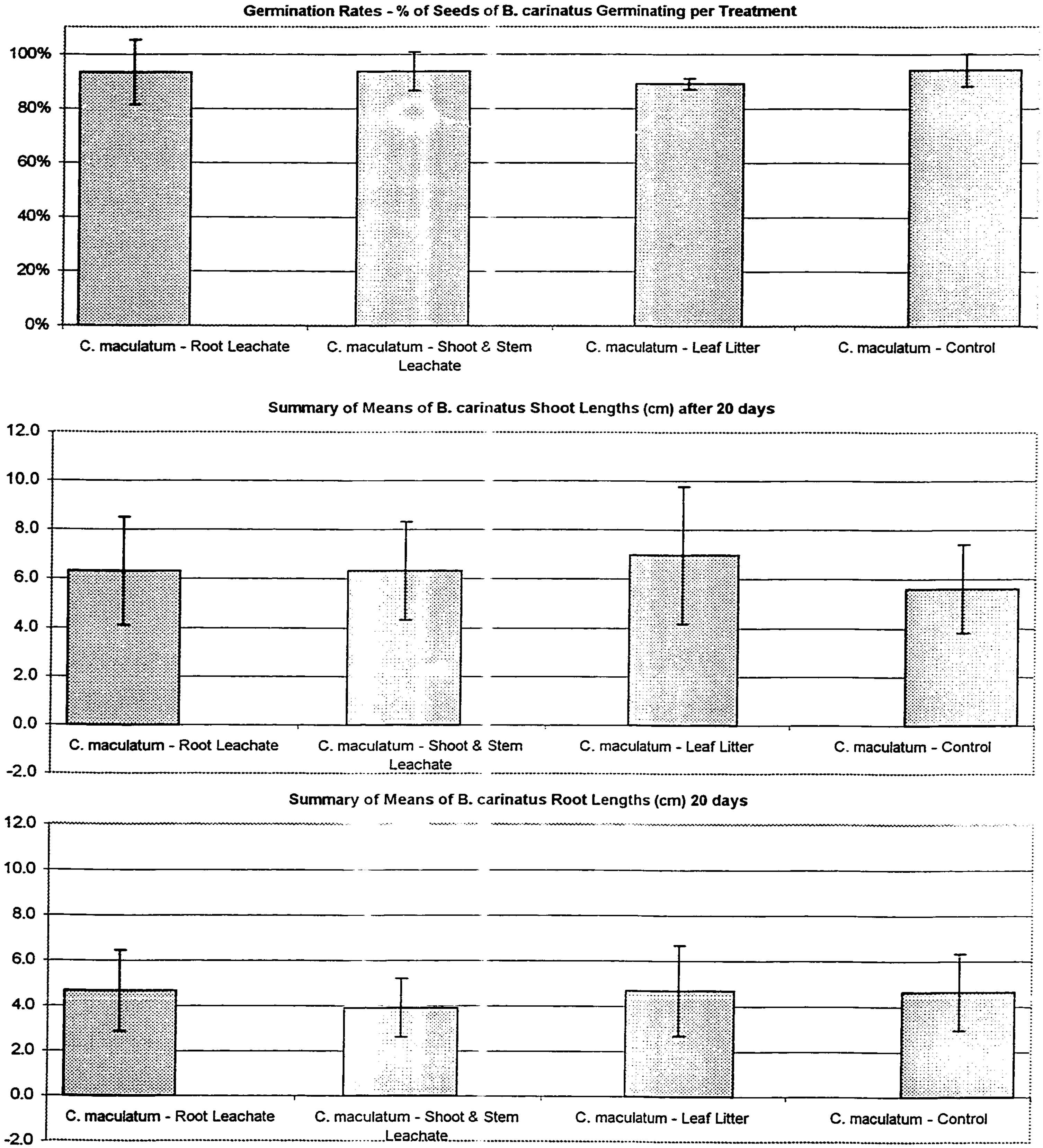
Summary of Means of B. carinatus Root Lengths (cm) after 20 days



Error Bars represent Standard Error

Figure 4 - Peak Growth Phase

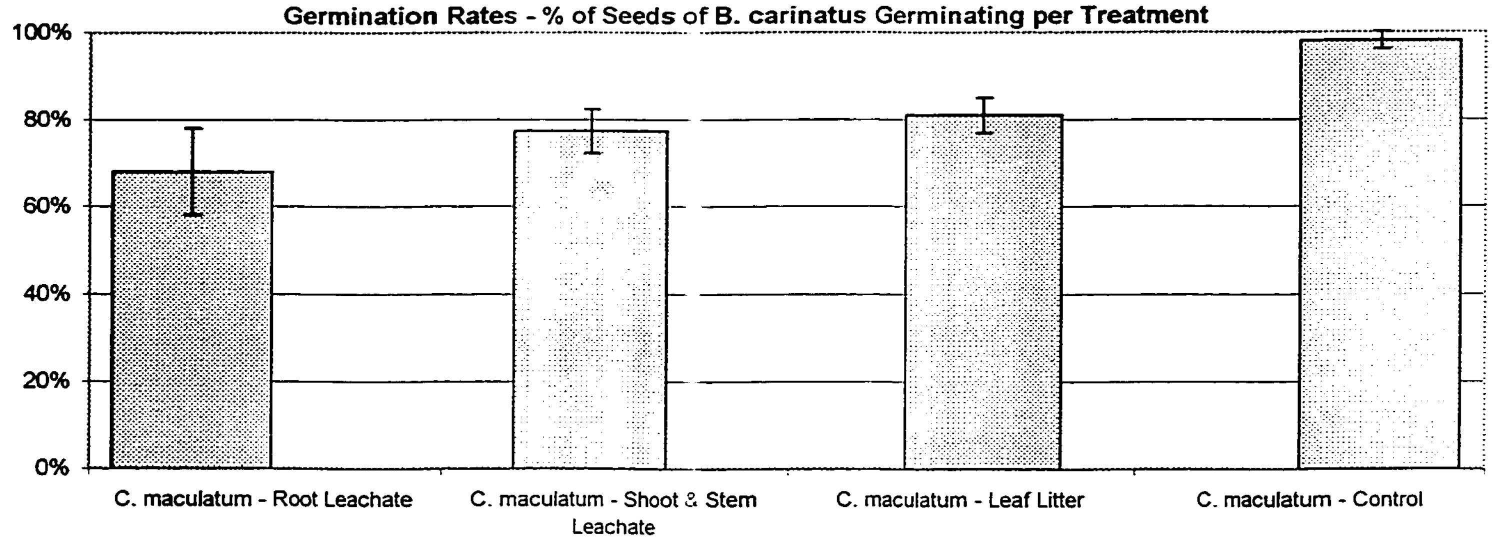
Seed germination, shoot growth and root growth were not inhibited by either of the C. maculatum leachates or by leaf litter

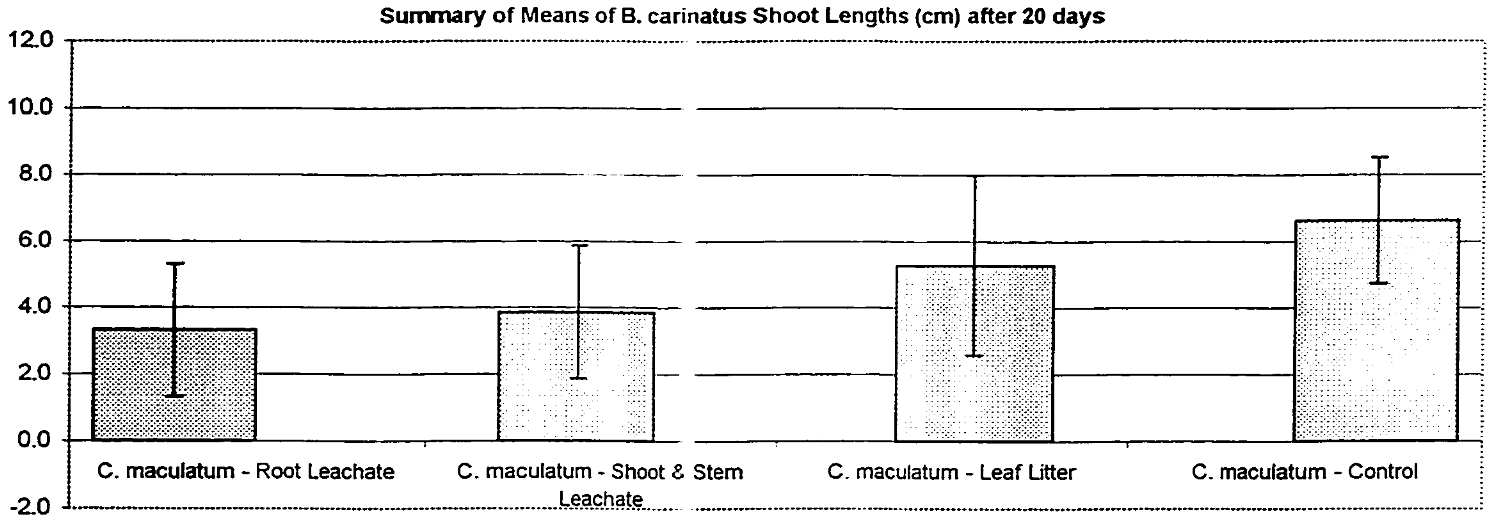


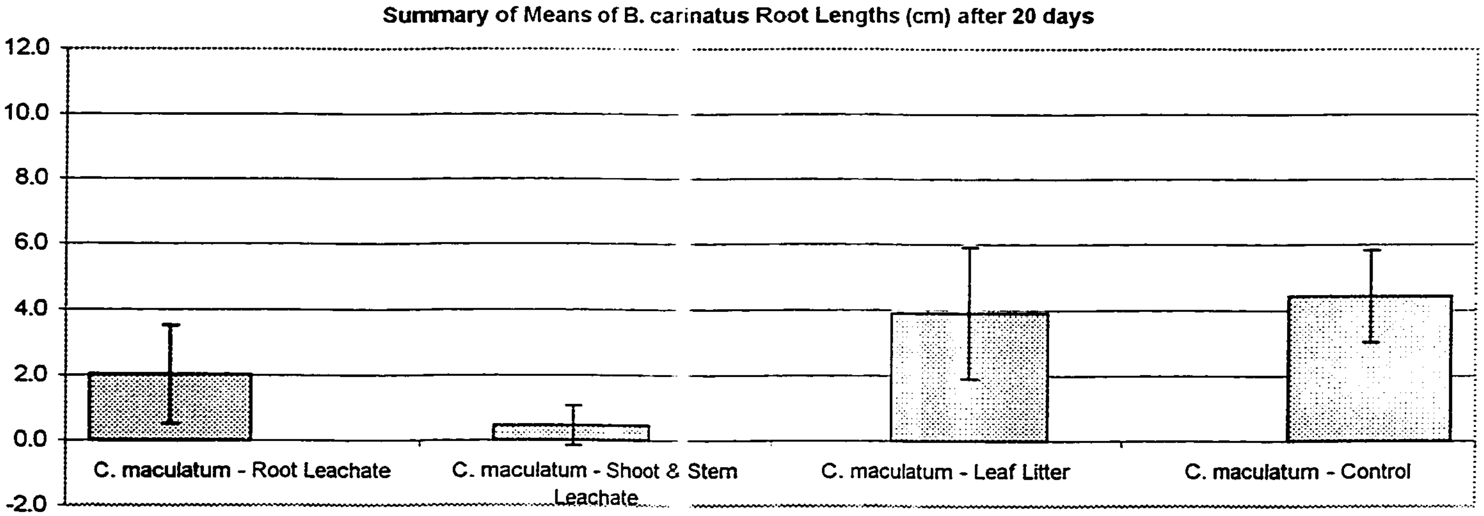
Error Bars represent Standard Error

Figure 5 - Senescence Phase

Seed germination was not inhibited by either the <u>C. maculatum</u> leachates or by leaf litter; root and shoot growth was slightly inhibited by both the <u>C. maculatum</u> leachates and leaf litter, with a more significant effect shown by Shoot and Stem Leachate on root growth.







Error Bars represent Standard Error

Appendix 1 - General Linear Model

Between Subject Factors

		Number
Treatment	Control	900
	Leaf Litter	900
	Root Leachate	900
	Shoot & Root Leachate	900
Phase	Early Growth	1200
	Peak Growth	1200
	Senescence	1200

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Significance
Intercept	Pillai's Trace	0.804	7337.875[a]	2.000	3587.000	0.000
	Wilk' Lambda	0.196	7337.875[a]	2.000	3587.000	0.000
	Hotelling's Trace	4.091	7337.875[a]	2.000	3587.000	0.000
	Roy's Largest Root	4.091	7337.875[a]	2.000	3587.000	0.000
Treatment	Pillai's Trace	0.310	219.738	6.000	7176.000	0.000
	Wilk' Lambda	0.698	235.858[a]	6.000	7174.000	0.000
	Hotelling's Trace	0.422	252.152	6.000	7172.000	0.000
	Roy's Largest Root	0.393	469.431	3.000	3588.000	0.000
Phase	Pillai's Trace	0.252	258.126	4.000	7176.000	0.000
	Wilk' Lambda	0.761	262.504[a]	4.000	7174.000	0.000
	Hotelling's Trace	0.298	266.890	4.000	7172.000	0.000
	Roy's Largest Root	0.224	402.571	2.000	3588.000	0.000
Treatment * Phase	Pillai's Trace	0.242	82.467	12.000	7176.000	0.000
	Wilk' Lambda	0.769	83.983[a]	12.000	7174.000	0.000
	Hotelling's Trace	0.286	85.503	12.000	7172.000	0.000
	Roy's Largest Root	0.220	131.462	6.000	3588.000	0.000

Notes

a. Exact statistics

b. The statistic is an upper bound on F that yields a lower bound on the significance level

c. Design: Intercept+Treatment+Phase+Treatment*Phase

Appendix 2 - Tests Between Subjects - Effects

Source	Dependent Variables	Type III Sum of the Squares	df	Mean Square	F	Sig
Corrected Model	Root	10175.652[a]	11	925.059	245.490	0.000
	Shoot	14221.697[b]	11	1292.882	206.136	0.000
Intercept	Root	39569.166	1	39569.166	10500.782	0.000
	Shoot	84538.470	1	84538.470	13478.730	0.000
Treatment	Root	5273.413	3	1757.804	466.482	0.000
	Shoot	4869.635	3	1623.212	258.803	0.000
Phase	Root	2414.264	2	1207.132	320.346	0.000
	Shoot	4808.611	2	2404.305	383.340	0.000
Treatment * Phase	Root	2487.975	6	414.662	110.042	0.000
	Shoot	4543.451	6	757.242	120.734	0.000
Error	Root	13520.342	3588	3.768		0.000
	Shoot	22503.903	3588	6.272		0.000
Total	Root	63265.160	3600			0.000
	Shoot	121264.070	3600			0.000
Corrected Total	Root	23695.994	3599			0.000
	Shoot	36725.600	3599			0.000

Notes

a. R Squared = .429 (Adjusted R Squared = .428)

b. R Squared = .387 (Adjusted R Squared = .385)

Appendix 3 - Shoot Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 1	**1**	6.7	0.4	5.6	8.7	7.4	7.5	12.6	4.2	3.0	8.1	4.2	8.0
	2	7.7	7.7	8.0	8.4	6.5	5.5	7.5	5.7	2.8	4.1	6.3	4.8
	3	5.6	2.6	5.8	7.6	6.5	5.5	8.0	5.0	4.8	4.5	6.0	3.0
	4	4.7	5.6	7.7	8.5	7.7	5.5	12.1	4.6	5.3	7.2	8.9	5.9
	5	7.8	3.0	6.6	7.4	5.2	6.0	9.4	6.6	5.5	5.4	5.5	6.0
	6	7.5	3.0	7.8	7.2	6.5	5.5	11.0	7.9	5.8	5.7	10.1	10.2
	7	6.9	6.0	5.5	6.9	7.6	6.3	8.3	4.9	3.5	3.4	8.0	7.9
	8	6.2	9.2	6.7	9.3	5.7	6.6	6.7	9.5	8.0	1.2	9.0	5.6
	9	7.7	5.8	4.1	7.4	4.4	8.5	9.0	8.5	3.2	3.8	5.2	7.5
	10	7.1	6.2	6.3	6.9	5.7	5.7	7.0	7.0	4.6	3.5	4.6	6.0
	11	6.6	8.2	4.1	9.1	3.9	7.0	12.3	6.5	4.5	3.9	7.6	3.1
	12	8.2	4.1	3.6	7.5	4.0	4.4	12.4	6.7	6.5	2.2	6.4	9.8
	13	7.5	2.3	5.8	4.7	6.0	5.6	8.3	5.6	1.0	4.7	6.3	6.3
	14	4.0	1.3	4.6	8.4	6.4	5.7	9.0	2.5	2.1	3.5	3.8	7.6
	15	2.6	8.5	7.2	7.2	6.2	6.7	11.6	7.5	2.5	2.4	6.5	7.5
	16	5.7	5.8	5.2	8.2	6.4	6.0	9.8	6.2	5.4	3.0	5.9	5.4
	17	5.5	3.8	6.8	6.7	7.0	7.4	8.2	7.3	2.6	4.5	2.8	8.2
	18	5.2	5.4	4.6	4.5	6.5	5.5	7.5	7.8	5.7	3.1	8.0	7.6
	19	4.5	3.1	4.6	7.1	5.7	6.3	9.0	6.5	6.5	5.2	5.1	7.2
	20	7.5	4.0	3.9	6.2	9.7	6.3	8.5	7.0	6.0	6.1	3.8	6.4
	21	5.7	7.1	6.9	9.2	8.4	2.0	8.9	5.7	5.1	4.7	4.0	6.6
	22	7.7	6.4	6.0	9.5	5.2	4.8	7.8	5.8	4.4	5.4	5.7	4.6
	23	5.7	1.0	4.3	7.6	4.3	3.6	8.4	6.5	6.0	0.9	5.5	4.5
	24	6.5	1.3	4.7	7.6	9.7	4.4	5.0	8.4	4.9	3.6	7.6	4.3
	25	7.0	2.6	6.4	8.0	10.9	5.3	7.5	6.1	6.2	4.4	9.0	5.6
	26	7.7	0.0	4.6	11.0	8.7	5.5	7.4	5.4	1.1	4.6	3.6	5.9
	27	8.1	0.0	5.7	7.5	7.2	5.0	8.5	2.5	4.9	4.4	7.4	3.6
	28	6.6	0.0	6.7	9.9	8.5	4.7	5.0	4.7	5.5	4.5	10.1	8.1
	29	8.5	0.0	7.0	7.6	6.5	4.0	8.0	5.6	2.0	6.0	9.3	6.2
	30	10.8	0.0	7.9	8.6	6.2	6.0	6.5	4.1	2.7	3.0	3.2	7.1
	31	10.7	0.0	3.7	7.9	4.7	4.0	8.2	6.5	5.6	5.4	6.6	4.8
	32	7.8	0.0	7.0	8.6	8.1	8.5	8.0	5.1	6.5	5.1	6.5	6.9
	33	5.6	0.0	3.0	8.0	8.3	7.4	11.5	5.9	6.6	5.5	9.9	7.2
	34	7.5	0.0	3.8	9.9	7.2	7.4	7.3	4.5	5.6	2.3	8.1	7.0
	35	7.8	0.0	7.0	10.1	6.4	8.0	10.0	3.0	3.4	7.1	9.0	3.0
	36	7.6	0.0	2.0	8.9	5.2	6.9	7.5	5.2	6.5	5.2	6.9	5.1
	37	6.9	0.0	0.8	5.5	[illegible]	5.4	6.3	4.5	6.6	6.7	7.1	5.8
	38	4.5	0.0	4.7	7.9	5.0	7.0	9.9	6.2	3.8	5.2	9.3	2.3
	39	6.5	0.0	6.6	8.2	3.2	7.2	5.0	5.2	5.1	5.6	11.3	4.6
	40	7.0	0.0	6.5	6.8	7.3	6.2	10.4	5.0	3.4	6.0	7.5	7.4
	41	6.4	0.0	2.3	6.1	6.5	3.4	10.0	4.0	2.5	3.9	5.6	8.6
	42	4.2	0.0	4.9	8.6	6.9	7.0	8.2	3.6	2.0	2.6	7.5	11.7
	43	3.9	0.0	6.2	6.4	5.6	7.7	9.5	3.0	3.4	0.5	6.2	4.6
	44	3.2	0.0	4.7	5.9	6.5	4.7	9.7	4.0	5.2	0.8	10.0	6.4
	45	3.6	0.0	6.5	8.5	5.4	5.4	8.6	6.0	0.9	0.0	7.5	5.5
	46	2.5	0.0	0.9	8.2	6.0	6.6	7.5	2.0	4.0	0.0	9.2	6.4
	47	1.1	0.0	6.2	6.5	6.3	3.9	10.0	5.7	5.6	0.0	7.7	5.0
	48	2.0	0.0	0.7	7.1	8.7	7.6	9.5	6.5	2.5	0.0	10.1	6.6
	49	2.0	0.0	0.8	7.2	7.5	7.7	10.9	6.2	4.0	0.0	5.6	8.7
	50	0.5	0.0	0.0	7.5	8.5	7.3	4.7	5.5	0.0	0.0	2.7	7.4
	51	0.0	0.0	0.0	6.6	8.2	6.9	4.0	5.7	0.0	0.0	0.0	5.1
	52	0.0	0.0	0.0	6.0	10.0	7.7	7.0	4.3	0.0	0.0	0.0	5.8
	53	0.0	0.0	0.0	10.8	7.0	3.5	4.2	3.6	0.0	0.0	0.0	9.4
	54	0.0	0.0	0.0	8.7	4.0	5.0	4.5	4.3	0.0	0.0	0.0	6.6
	55	0.0	0.0	0.0	6.5	9.2	0.0	6.7	0.0	0.0	0.0	0.0	5.4
	56	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
	57	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2
	58	0.0	0.0	0.0	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7
	59	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 3 - Shoot Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 2	**1**	2.7	2.1	0.2	6.9	7.5	5.6	9.9	5.2	4.1	2.6	9.5	5.0
	2	5.2	1.1	0.7	9.2	9.0	6.2	3.6	6.5	4.0	7.0	9.0	7.3
	3	3.8	2.2	2.4	8.2	6.8	7.4	5.7	6.0	3.1	6.0	4.8	4.0
	4	6.3	1.9	1.0	9.7	7.0	5.7	6.4	4.3	5.1	4.6	4.0	7.9
	5	5.8	0.7	1.0	5.9	6.5	6.2	3.6	5.5	7.0	6.6	6.5	6.1
	6	2.7	2.0	1.2	8.5	4.5	7.2	7.2	8.0	4.6	8.1	9.5	8.6
	7	4.6	6.5	1.0	6.9	6.6	5.7	7.4	5.0	6.6	4.2	6.4	13.0
	8	3.1	7.6	1.2	8.9	7.8	6.4	7.8	7.3	5.4	4.5	5.0	6.6
	9	5.7	6.7	2.7	6.7	6.0	6.7	7.6	5.5	1.1	1.9	4.5	10.0
	10	1.2	3.2	4.4	9.5	8.0	7.1	6.4	6.0	6.0	4.5	7.3	7.9
	11	1.0	6.6	2.1	8.2	6.0	7.5	6.9	7.0	4.5	4.6	5.3	11.0
	12	0.4	4.4	3.6	10.1	5.9	7.6	8.2	6.0	5.1	6.2	6.6	6.5
	13	1.1	1.9	5.3	7.6	4.[illegible]	8.0	4.0	4.7	5.2	3.3	9.8	6.3
	14	2.1	6.6	5.4	7.5	6.0	9.0	7.2	6.0	3.0	6.1	8.2	6.1
	15	3.4	6.9	2.7	9.8	3.5	4.4	5.7	6.2	3.2	5.4	6.4	8.4
	16	2.3	5.1	2.6	8.5	6.7	7.5	4.4	7.7	7.0	5.3	4.5	4.1
	17	2.1	4.4	8.5	8.2	7.3	7.6	5.9	7.7	5.9	5.7	7.5	5.1
	18	0.4	2.5	0.7	9.1	4.0	5.9	7.6	5.0	7.2	6.7	5.0	5.5
	19	0.0	6.8	5.4	8.9	6.7	7.5	3.7	7.0	4.7	4.5	7.7	6.0
	20	0.0	8.5	3.4	7.5	8.3	5.5	8.3	4.8	5.5	4.3	5.8	9.0
	21	0.0	5.9	9.0	6.8	6.5	6.0	10.0	4.3	9.0	5.2	9.6	7.0
	22	0.0	7.5	4.0	9.1	7.3	6.3	10.4	6.0	7.5	4.1	7.2	6.6
	23	0.0	1.2	6.0	6.4	8.4	4.9	8.2	5.9	6.6	2.5	4.8	7.9
	24	0.0	4.5	5.5	4.8	7.5	6.0	8.5	4.0	5.0	5.2	4.3	7.1
	25	0.0	3.4	0.7	8.1	5.5	8.1	10.0	5.5	3.7	4.6	8.9	8.0
	26	0.0	6.4	6.7	8.9	5.5	6.2	9.7	7.0	3.2	3.3	6.7	6.0
	27	0.0	7.6	5.7	7.5	7.2	6.7	8.0	5.5	10.4	5.3	7.4	9.2
	28	0.0	2.3	6.0	8.6	4.9	6.8	7.4	5.0	8.0	4.6	7.8	6.3
	29	0.0	7.0	6.7	11.1	5.4	7.0	10.2	7.1	5.6	2.3	4.0	5.4
	30	0.0	5.6	8.5	8.4	6.6	7.6	7.7	3.9	9.2	4.0	5.1	7.8
	31	0.0	2.1	7.1	9.5	6.5	5.5	6.0	5.4	7.2	4.2	7.6	7.6
	32	0.0	2.3	7.9	8.6	5.4	9.2	11.1	3.5	5.6	3.7	5.0	8.5
	33	0.0	3.5	8.0	9.9	7.0	6.8	9.7	4.0	6.6	5.1	5.1	7.7
	34	0.0	0.0	7.6	8.4	5.9	5.5	5.2	4.0	2.5	4.8	5.0	8.1
	35	0.0	0.0	8.7	6.4	8.2	4.5	8.6	7.0	0.0	4.6	3.0	6.9
	36	0.0	0.0	3.5	7.3	6.5	4.8	9.5	5.2	0.0	4.9	8.2	6.1
	37	0.0	0.0	5.8	6.6	6.5	7.5	6.6	6.7	0.0	3.1	8.7	8.0
	38	0.0	0.0	3.5	10.2	8.4	8.1	8.6	6.2	0.0	3.4	7.3	6.6
	39	0.0	0.0	6.0	7.9	8.3	6.3	6.5	5.9	0.0	3.6	4.1	7.5
	40	0.0	0.0	6.7	9.9	6.7	4.0	4.4	6.0	0.0	4.7	4.2	9.0
	41	0.0	0.0	7.3	10.5	6.9	8.0	7.5	7.0	0.0	3.1	6.0	5.1
	42	0.0	0.0	4.0	5.9	6.7	9.1	6.4	7.2	0.0	2.7	10.3	9.4
	43	0.0	0.0	5.2	8.7	8.3	5.4	4.0	6.2	0.0	4.1	8.1	9.0
	44	0.0	0.0	7.6	8.6	7.8	7.2	7.9	4.0	0.0	3.1	8.7	10.1
	45	0.0	0.0	6.7	7.1	8.5	6.7	10.0	5.5	0.0	4.0	4.6	7.5
	46	0.0	0.0	6.0	7.5	8.7	6.7	7.5	6.4	0.0	2.5	6.0	4.5
	47	0.0	0.0	5.7	9.8	5.6	5.6	7.8	5.2	0.0	0.0	5.3	5.5
	48	0.0	0.0	6.7	7.2	7.5	7.4	6.9	4.7	0.0	0.0	8.0	5.2
	49	0.0	0.0	9.0	8.3	5.9	7.0	5.8	3.9	0.0	0.0	0.0	6.0
	50	0.0	0.0	0.0	5.8	5.7	9.9	9.4	5.2	0.0	0.0	0.0	6.6
	51	0.0	0.0	0.0	8.9	7.0	7.6	8.3	7.0	0.0	0.0	0.0	6.5
	52	0.0	0.0	0.0	9.5	9.[illegible]	6.5	8.8	7.0	0.0	0.0	0.0	5.4
	53	0.0	0.0	0.0	6.7	4.7	7.0	6.8	5.9	0.0	0.0	0.0	7.5
	54	0.0	0.0	0.0	8.4	6.7	8.1	9.2	5.0	0.0	0.0	0.0	5.7
	55	0.0	0.0	0.0	5.9	8.0	6.5	6.7	7.5	0.0	0.0	0.0	3.9
	56	0.0	0.0	0.0	10.5	7.4	8.6	4.0	3.0	0.0	0.0	0.0	5.0
	57	0.0	0.0	0.0	0.0	3.3	6.9	0.0	6.4	0.0	0.0	0.0	8.0
	58	0.0	0.0	0.0	0.0	9.5	4.0	0.0	3.8	0.0	0.0	0.0	5.1
	59	0.0	0.0	0.0	0.0	5.8	0.0	0.0	5.5	0.0	0.0	0.0	5.7
	60	0.0	0.0	0.0	0.0	4.5	7.5	7.8	6.9	0.0	0.0	0.0	0.0

Appendix 3 - Shoot Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 3	**1**	2.0	4.6	5.3	9.4	6.0	6.3	9.8	4.4	5.0	6.2	3.0	6.0
	2	0.0	2.7	2.2	9.7	7.2	7.8	8.4	7.5	5.5	5.3	2.9	9.9
	3	0.0	0.7	8.2	10.4	8.3	7.1	10.1	5.2	3.5	4.0	3.6	6.0
	4	0.0	6.0	7.5	8.0	8.5	6.0	3.9	5.7	4.4	5.1	4.5	6.7
	5	0.0	5.4	3.4	7.0	7.5	7.7	6.2	8.0	6.5	2.2	5.5	11.5
	6	0.0	2.1	7.5	7.2	6.1	7.6	6.8	5.7	6.4	5.0	4.4	5.5
	7	0.0	0.8	2.0	7.3	3.6	7.9	7.1	6.4	4.0	4.6	5.9	7.8
	8	0.0	0.6	0.5	8.7	7.5	9.5	5.8	6.0	4.6	5.6	7.1	7.4
	9	0.0	0.0	2.4	8.3	2.4	7.2	10.0	5.0	9.1	2.5	10.5	6.0
	10	0.0	0.0	3.4	6.4	6.0	7.4	6.6	6.5	8.8	1.9	3.0	5.0
	11	0.0	0.0	3.3	7.9	8.0	6.7	7.7	3.5	6.6	3.0	3.7	8.8
	12	0.0	0.0	5.0	7.2	3.2	6.9	3.8	5.5	5.0	4.3	9.0	7.5
	13	0.0	0.0	4.6	6.4	7.7	6.3	6.5	5.9	7.9	3.1	8.9	7.3
	14	0.0	0.0	3.4	5.3	7.1	7.4	3.5	6.7	8.2	4.1	4.4	6.7
	15	0.0	0.0	0.6	7.2	9.5	7.2	7.6	3.8	5.6	4.6	7.3	6.8
	16	0.0	0.0	1.2	8.5	4.0	10.4	12.0	6.5	3.5	5.1	3.9	5.6
	17	0.0	0.0	0.3	7.6	6.0	8.4	6.6	6.4	6.0	5.4	4.4	3.0
	18	0.0	0.0	3.7	7.9	5.7	6.3	8.9	3.9	7.6	4.6	5.4	5.8
	19	0.0	0.0	7.8	8.4	4.5	7.7	8.7	5.7	9.0	3.9	6.1	5.0
	20	0.0	0.0	6.5	8.6	4.7	7.5	9.6	4.0	7.5	4.2	2.5	5.9
	21	0.0	0.0	3.6	8.7	5.9	9.2	9.8	7.7	9.0	5.7	4.1	7.8
	22	0.0	0.0	6.2	7.7	4.4	3.7	8.2	7.0	6.6	4.5	2.3	7.4
	23	0.0	0.0	6.7	6.0	4.1	8.1	10.9	6.4	3.9	4.7	2.6	7.3
	24	0.0	0.0	3.0	8.2	6.0	5.5	8.4	5.6	5.0	3.6	5.5	5.6
	25	0.0	0.0	8.0	7.7	4.0	7.4	7.4	5.5	9.6	7.6	7.7	6.4
	26	0.0	0.0	3.0	7.5	4.2	7.2	5.2	7.0	3.8	4.0	2.9	8.9
	27	0.0	0.0	2.8	9.5	3.5	8.2	8.9	5.0	3.5	3.6	7.6	5.0
	28	0.0	0.0	3.0	6.5	7.6	8.1	9.5	3.5	4.1	6.9	7.4	7.5
	29	0.0	0.0	1.5	4.9	5.6	8.4	12.5	6.2	3.5	2.8	3.5	5.5
	30	0.0	0.0	2.5	8.6	6.6	7.5	7.9	5.9	3.7	4.7	3.4	7.6
	31	0.0	0.0	2.1	7.0	9.0	4.9	7.7	4.7	6.4	3.7	7.5	6.7
	32	0.0	0.0	0.9	8.3	7.0	7.4	6.7	6.4	4.1	5.4	4.9	8.0
	33	0.0	0.0	3.5	5.4	7.5	9.2	8.4	5.7	3.9	7.5	6.0	10.5
	34	0.0	0.0	2.6	4.9	7.5	10.0	9.5	6.9	5.6	4.4	5.9	5.4
	35	0.0	0.0	6.2	6.9	6.[illegible]	9.2	8.1	6.2	3.7	5.4	5.4	5.5
	36	0.0	0.0	3.6	4.3	8.6	8.6	4.3	6.1	6.1	3.3	10.0	6.0
	37	0.0	0.0	6.6	7.9	5.5	6.4	3.9	6.3	3.5	3.9	6.5	4.9
	38	0.0	0.0	6.3	5.2	7.6	5.0	7.9	8.5	2.6	6.0	8.8	7.6
	39	0.0	0.0	4.7	8.5	4.2	6.2	7.3	9.7	0.7	7.5	7.7	8.4
	40	0.0	0.0	3.5	9.7	8.5	8.5	5.9	8.4	5.6	3.2	8.1	8.6
	41	0.0	0.0	3.7	8.1	8.5	7.6	6.4	5.4	3.0	2.1	8.6	6.2
	42	0.0	0.0	0.5	8.7	10.0	7.4	4.5	5.5	3.0	4.2	8.7	8.3
	43	0.0	0.0	1.0	6.5	5.6	7.4	8.4	5.0	3.5	0.0	7.6	5.0
	44	0.0	0.0	0.0	5.7	6.2	9.0	6.0	6.5	3.0	0.0	7.5	10.4
	45	0.0	0.0	0.0	4.5	6.5	6.4	7.1	8.5	0.0	0.0	7.4	6.3
	46	0.0	0.0	0.0	4.7	0.0	7.4	8.1	6.5	0.0	0.0	6.1	7.2
	47	0.0	0.0	0.0	4.8	0.0	6.0	6.8	8.4	0.0	0.0	0.0	5.6
	48	0.0	0.0	0.0	8.5	0.0	7.9	8.0	6.6	0.0	0.0	0.0	7.0
	49	0.0	0.0	0.0	8.4	0	8.2	6.8	7.9	0.0	0.0	0.0	7.9
	50	0.0	0.0	0.0	9.0	0.0	8.4	3.9	8.2	0.0	0.0	0.0	8.2
	51	0.0	0.0	0.0	8.4	0.0	0.0	8.9	7.5	0.0	0.0	0.0	7.3
	52	0.0	0.0	0.0	4.3	0.0	0.0	8.1	7.8	0.0	0.0	0.0	7.5
	53	0.0	0.0	0.0	5.9	0.0	0.0	8.4	6.5	0.0	0.0	0.0	8.1
	54	0.0	0.0	0.0	5.8	0.0	0.0	0.0	6.7	0.0	0.0	0.0	5.4
	55	0.0	0.0	0.0	5.4	0.0	0.0	0.0	8.0	0.0	0.0	0.0	3.2
	56	0.0	0.0	0.0	7.5	0.0	0.0	0.0	4.0	0.0	0.0	0.0	6.9
	57	0.0	0.0	0.0	6.3	0.0	0.0	0.0	6.1	0.0	0.0	0.0	6.4
	58	0.0	0.0	0.0	7.1	0.0	0.0	0.0	5.9	0.0	0.0	0.0	5.3
	59	0.0	0.0	0.0	7.2	0.0	0.0	0.0	6.3	0.0	0.0	0.0	8.3
	60	0.0	0.0	0.0	6.3	0.0	0.0	0.0	6.5	0.0	0.0	0.0	6.1

Appendix 3 - Shoot Details - Raw Results

		Early Growth				Peak Growth				Senescence			
Tray	Item	Experiment 1 - Root Leachate	Experiment 2 - Shoot & Stem Leachate	Experiment 3 - Leaf Litter	Experiment 4 - Control	Experiment 1 - Root Leachate	Experiment 2 - Shoot & Stem Leachate	Experiment 3 - Leaf Litter	Experiment 4 - Control	Experiment 1 - Root Leachate	Experiment 2 - Shoot & Stem Leachate	Experiment 3 - Leaf Litter	Experiment 4 - Control
Tray 4	**1**	3.6	8.0	6.6	5.9	5.[illegible]	5.0	12.2	6.9	4.4	6.8	4.7	6.7
	2	0.0	4.4	9.9	6.9	5.[illegible]	8.3	9.2	7.0	3.6	8.2	6.5	8.5
	3	0.0	2.5	5.6	5.9	7.[illegible]	10.4	6.6	6.9	5.9	4.6	5.1	3.9
	4	0.0	2.6	4.6	7.6	7.[illegible]	9.1	12.0	6.3	4.5	6.5	7.2	7.4
	5	0.0	1.2	4.3	7.4	5.[illegible]	8.2	8.6	6.2	2.7	4.4	6.5	5.1
	6	0.0	0.4	7.3	6.5	6.[illegible]	8.3	7.9	7.5	2.6	5.6	6.6	6.2
	7	0.0	6.1	6.0	6.9	7.[illegible]	3.9	7.3	6.9	4.2	6.9	8.1	8.0
	8	0.0	0.9	6.7	6.0	6.[illegible]	8.2	8.3	5.0	3.7	2.5	4.3	11.1
	9	0.0	4.6	0.8	6.3	7.[illegible]	5.0	7.7	5.4	2.0	6.5	7.4	6.6
	10	0.0	5.1	2.6	5.0	7[illegible]	7.3	4.9	7.5	3.1	5.4	6.3	8.5
	11	0.0	6.0	4.5	8.9	7.[illegible]	9.3	7.7	7.3	4.9	4.3	6.4	6.3
	12	0.0	7.4	5.1	10.5	7[illegible]	8.9	11.6	4.0	3.6	5.8	8.9	11.2
	13	0.0	3.6	4.9	9.1	6.[illegible]	7.7	9.7	6.5	5.0	5.1	4.6	6.7
	14	0.0	3.9	7.0	5.7	6[illegible]	8.5	7.9	6.6	4.5	5.3	9.2	4.5
	15	0.0	1.8	7.5	6.8	8[illegible]	7.6	7.4	5.8	4.8	6.9	6.1	6.8
	16	0.0	0.7	8.1	9.1	7[illegible]	7.7	8.3	6.0	3.4	5.2	9.6	6.6
	17	0.0	1.0	8.0	6.4	8.[illegible]	5.9	9.5	5.5	3.4	6.6	4.9	8.8
	18	0.0	0.5	6.4	5.9	5.[illegible]	6.9	10.2	5.5	4.3	5.2	9.1	5.9
	19	0.0	0.8	6.2	6.4	7.[illegible]	7.3	10.0	4.6	4.0	6.0	8.1	9.3
	20	0.0	0.0	5.2	6.2	5.[illegible]	7.1	4.1	7.5	5.9	7.0	8.0	8.5
	21	0.0	0.0	7.8	7.0	4.[illegible]	7.7	9.4	6.0	4.5	7.8	5.2	6.7
	22	0.0	0.0	5.9	9.2	6.[illegible]	6.9	9.3	5.4	4.0	6.5	8.6	5.2
	23	0.0	0.0	4.1	6.5	5.[illegible]	8.7	5.3	4.0	8.1	3.9	4.1	6.3
	24	0.0	0.0	3.0	3.6	6.[illegible]	4.1	6.9	5.5	5.4	6.5	7.2	5.6
	25	0.0	0.0	5.5	5.3	6.[illegible]	8.7	4.4	5.5	5.5	7.4	7.9	5.2
	26	0.0	0.0	2.2	5.9	5[illegible]	8.2	4.5	8.4	6.0	4.5	5.9	7.4
	27	0.0	0.0	2.9	6.8	6[illegible]	6.6	3.8	5.2	3.4	4.9	8.6	8.8
	28	0.0	0.0	2.8	6.9	8[illegible]	9.8	8.1	5.0	7.2	6.5	4.0	5.5
	29	0.0	0.0	2.7	6.2	7.[illegible]	7.5	9.6	7.0	9.0	8.0	2.9	9.5
	30	0.0	0.0	4.4	7.2	8.[illegible]	9.3	3.9	6.0	5.2	6.6	4.5	8.6
	31	0.0	0.0	4.0	7.8	6.[illegible]	8.2	6.8	4.6	3.1	5.2	5.0	6.9
	32	0.0	0.0	5.0	5.7	7.[illegible]	4.8	7.3	6.1	4.1	7.3	7.5	5.2
	33	0.0	0.0	4.2	7.8	7.[illegible]	6.1	11.0	7.2	2.8	4.7	7.6	6.3
	34	0.0	0.0	3.2	6.7	6[illegible]	7.6	8.5	4.6	4.5	4.0	3.9	11.5
	35	0.0	0.0	4.2	8.3	6[illegible]	6.0	6.3	5.1	3.1	7.0	4.2	5.0
	36	0.0	0.0	2.7	7.9	8.[illegible]	5.0	4.2	6.4	3.5	4.2	7.1	7.1
	37	0.0	0.0	7.2	7.6	8.[illegible]	5.9	6.5	6.0	5.9	5.2	5.7	6.3
	38	0.0	0.0	6.9	7.0	5[illegible]	9.1	7.5	6.5	6.3	6.1	7.3	7.7
	39	0.0	0.0	3.2	7.1	8[illegible]	5.6	7.9	6.4	7.3	4.5	4.9	4.6
	40	0.0	0.0	7.1	7.5	7[illegible]	6.6	5.1	6.4	1.4	5.5	5.1	3.7
	41	0.0	0.0	2.2	5.5	6[illegible]	7.3	7.6	6.2	0.0	3.4	7.3	8.0
	42	0.0	0.0	2.7	7.9	6.[illegible]	6.8	12.4	6.0	0.0	3.5	4.7	4.2
	43	0.0	0.0	5.9	6.9	8.[illegible]	8.0	7.9	10.2	0.0	4.0	9.5	8.1
	44	0.0	0.0	3.7	8.8	6.[illegible]	4.7	7.7	6.4	0.0	7.3	6.6	7.6
	45	0.0	0.0	1.0	6.8	8.[illegible]	5.6	12.3	6.5	0.0	5.0	5.0	7.7
	46	0.0	0.0	1.9	9.8	6[illegible]	7.6	8.9	6.0	0.0	7.0	5.4	4.6
	47	0.0	0.0	0.0	7.8	5[illegible]	7.6	10.8	4.9	0.0	7.5	9.5	5.5
	48	0.0	0.0	0.0	7.7	6[illegible]	7.7	12.0	5.2	0.0	4.5	8.8	5.9
	49	0.0	0.0	0.0	6.1	6[illegible]	5.6	9.1	6.2	0.0	5.5	0.0	5.9
	50	0.0	0.0	0.0	9.7	7[illegible]	6.3	9.8	6.3	0.0	3.2	0.0	5.3
	51	0.0	0.0	0.0	5.8	7[illegible]	6.1	6.8	5.3	0.0	4.5	0.0	4.0
	52	0.0	0.0	0.0	10.2	7.[illegible]	5.6	8.5	4.5	0.0	0.0	0.0	5.8
	53	0.0	0.0	0.0	5.8	7.[illegible]	7.4	0.0	4.3	0.0	0.0	0.0	7.9
	54	0.0	0.0	0.0	6.7	7.[illegible]	9.1	0.0	4.0	0.0	0.0	0.0	6.6
	55	0.0	0.0	0.0	8.5	7[illegible]	3.3	0.0	4.5	0.0	0.0	0.0	6.1
	56	0.0	0.0	0.0	6.9	7.[illegible]	7.2	0.0	0.0	0.0	0.0	0.0	5.2
	57	0.0	0.0	0.0	7.7	6[illegible]	5.1	0.0	0.0	0.0	0.0	0.0	8.2
	58	0.0	0.0	0.0	8.9	8.[illegible]	7.0	0.0	0.0	0.0	0.0	0.0	7.7
	59	0.0	0.0	0.0	11.2	9[illegible]	4.0	0.0	0.0	0.0	0.0	0.0	6.7
	60	0.0	0.0	0.0	0.0	7.[illegible]	4.6	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 3 - Shoot Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 5	**1**	3.7	2.0	6.6	6.0	8	7.6	8.6	6.2	6.4	5.8	3.7	9.7
	2	2.3	4.8	8.2	9.2	7	6.2	7.3	5.9	2.7	3.2	7.9	6.1
	3	5.7	7.3	4.6	7.5	7	9.6	8.5	8.0	3.5	4.3	4.1	6.0
	4	7.3	5.2	9.5	7.6	7	7.0	8.1	7.5	5.6	5.3	6.2	4.9
	5	3.2	3.2	6.9	10.7	6	7.1	7.4	6.5	6.1	4.7	8.9	8.1
	6	4.2	7.5	3.1	5.8	7	7.1	9.0	6.2	2.5	5.1	6.2	10.3
	7	6.1	6.3	3.1	6.1	4	4.1	11.4	7.2	2.4	7.2	6.3	5.5
	8	2.2	4.1	4.6	6.4	8	8.0	7.2	5.5	6.6	4.7	5.1	3.2
	9	3.0	2.5	2.2	6.8	6	7.5	9.9	8.0	5.9	4.8	5.9	9.9
	10	3.0	9.1	8.1	5.0	5	10.0	12.2	8.0	5.1	6.9	7.5	8.0
	11	3.1	5.5	2.4	8.8	8	7.5	6.6	9.0	4.6	8.1	5.1	6.0
	12	2.1	6.2	8.0	10.4	7	7.5	10.9	9.0	4.9	8.0	8.8	4.7
	13	2.0	5.9	8.1	9.2	7	7.3	8.1	6.7	8.5	5.6	4.5	5.9
	14	4.5	1.0	8.7	6.5	7	7.0	7.9	4.5	9.2	5.7	10.0	7.0
	15	4.2	3.2	6.6	5.9	6	7.4	8.3	3.5	6.7	3.5	5.4	4.9
	16	0.7	3.0	7.1	7.1	6	3.6	9.0	4.5	4.1	5.0	3.1	6.9
	17	1.0	1.2	7.6	9.4	7	5.2	6.4	7.4	5.2	5.6	11.2	8.0
	18	1.1	2.0	7.2	4.7	4	6.9	7.2	7.5	3.0	6.1	9.1	4.7
	19	0.9	0.0	4.2	7.3	7	7.5	5.2	6.8	6.5	7.6	6.5	6.7
	20	1.1	0.0	3.6	7.9	8	6.2	7.9	7.1	4.6	4.9	7.4	7.3
	21	1.9	0.0	2.1	6.6	8	7.1	7.4	8.5	4.2	6.5	7.4	8.1
	22	2.8	0.0	6.1	8.2	7	6.5	9.6	5.5	6.0	6.8	6.4	7.6
	23	0.0	0.0	4.4	9.7	7	7.6	9.9	7.2	2.3	6.4	5.5	3.7
	24	0.0	0.0	5.1	8.3	6	7.7	4.6	6.5	5.2	6.1	9.9	5.7
	25	0.0	0.0	6.3	9.8	5	7.4	7.4	7.2	2.1	6.0	9.8	6.5
	26	0.0	0.0	6.3	6.0	5	3.3	9.4	7.8	3.5	6.3	6.1	8.3
	27	0.0	0.0	5.1	8.6	7	6.5	9.8	5.8	1.9	7.2	9.2	7.7
	28	0.0	0.0	2.6	6.8	8	7.7	7.1	5.9	5.3	7.0	8.0	7.3
	29	0.0	0.0	3.6	8.9	7	7.7	6.5	5.0	3.4	5.6	8.9	4.9
	30	0.0	0.0	8.2	6.8	4	5.1	7.7	5.6	4.6	6.0	6.8	8.8
	31	0.0	0.0	3.6	9.4	8	7.6	6.3	4.0	5.7	5.9	6.3	5.5
	32	0.0	0.0	8.5	8.0	7	6.5	7.0	7.0	4.6	3.2	5.8	9.3
	33	0.0	0.0	4.4	6.3	7	8.4	3.9	6.1	3.6	4.2	7.4	4.0
	34	0.0	0.0	5.7	7.4	7	3.7	3.8	5.0	4.3	6.6	7.2	8.9
	35	0.0	0.0	6.7	8.8	8	6.4	10.1	5.6	5.6	6.1	9.4	6.9
	36	0.0	0.0	1.2	8.4	6	4.3	8.4	5.0	5.1	6.7	4.4	6.5
	37	0.0	0.0	6.0	9.7	7	5.8	7.5	5.4	6.2	7.0	5.2	7.0
	38	0.0	0.0	2.5	6.0	8	4.5	9.6	6.4	0.0	7.1	8.9	9.1
	39	0.0	0.0	6.5	6.3	5	4.9	7.8	7.5	0.0	5.1	6.3	7.5
	40	0.0	0.0	1.3	7.5	6	7.5	8.5	6.1	0.0	5.3	4.7	5.3
	41	0.0	0.0	0.0	6.8	6	6.3	6.4	6.0	0.0	5.0	8.1	9.0
	42	0.0	0.0	0.0	6.2	8	5.2	7.4	7.3	0.0	3.7	4.4	7.1
	43	0.0	0.0	0.0	4.9	7	5.9	6.3	6.9	0.0	9.5	3.9	6.2
	44	0.0	0.0	0.0	10.7	6	7.5	8.2	6.4	0.0	7.2	4.9	5.4
	45	0.0	0.0	0.0	8.6	7	5.3	8.4	5.6	0.0	7.1	9.4	5.9
	46	0.0	0.0	0.0	9.7	7	4.1	4.5	5.9	0.0	6.4	7.6	7.7
	47	0.0	0.0	0.0	7.7	4	4.9	7.3	6.7	0.0	6.9	2.6	5.9
	48	0.0	0.0	0.0	5.6	8	6.6	8.4	5.5	0.0	5.3	10.0	8.4
	49	0.0	0.0	0.0	8.2	3	7.4	9.8	5.1	0.0	4.4	4.9	5.0
	50	0.0	0.0	0.0	6.6	3	6.8	5.3	6.7	0.0	0.0	5.9	7.4
	51	0.0	0.0	0.0	5.8	9	5.4	0.0	7.3	0.0	0.0	5.2	5.8
	52	0.0	0.0	0.0	8.6	7	5.6	0.0	6.0	0.0	0.0	0.0	7.9
	53	0.0	0.0	0.0	9.2	7	5.9	0.0	5.9	0.0	0.0	0.0	7.6
	54	0.0	0.0	0.0	6.6	7	6.8	0.0	0.0	0.0	0.0	0.0	6.6
	55	0.0	0.0	0.0	8.9	5	7.5	0.0	0.0	0.0	0.0	0.0	6.1
	56	0.0	0.0	0.0	10.6	6	8.2	0.0	0.0	0.0	0.0	0.0	5.2
	57	0.0	0.0	0.0	7.9	7	7.4	0.0	0.0	0.0	0.0	0.0	7.4
	58	0.0	0.0	0.0	0.0	8	7.0	0.0	0.0	0.0	0.0	0.0	6.4
	59	0.0	0.0	0.0	0.0	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	60	0.0	0.0	0.0	0.0	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 4 - Root Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 1	1	7.2	0.0	2.7	10.7	3.9	5.0	4.5	3.4	1.1	0.9	2.0	6.2
	2	5.1	3.9	4.4	8.6	5.3	5.2	3.5	3.9	2.5	0.5	5.3	4.0
	3	3.5	4.3	6.7	5.9	5.9	5.2	4.0	3.2	2.0	0.8	4.6	4.0
	4	3.4	7.1	3.1	6.2	5.9	5.5	6.3	5.5	3.0	0.2	6.5	5.6
	5	4.8	4.6	5.2	3.2	3.4	4.5	3.5	8.0	1.2	0.3	4.9	4.0
	6	3.7	0.7	4.4	3.4	4.7	4.0	6.0	7.2	3.5	2.7	5.3	7.5
	7	3.6	3.1	4.7	2.6	4.0	4.0	4.5	3.2	4.0	0.4	3.5	8.3
	8	5.1	4.9	5.5	4.5	3.6	5.4	4.6	6.2	3.7	2.0	5.6	2.4
	9	6.5	4.3	4.2	5.7	2.5	5.1	4.3	6.1	2.9	0.5	2.5	3.9
	10	4.6	4.5	5.4	7.5	3.0	4.7	4.0	4.5	0.5	0.1	7.1	4.3
	11	5.4	3.3	3.6	10.0	3.6	5.4	5.7	3.1	3.6	0.2	5.5	2.2
	12	4.1	2.3	3.3	5.1	2.0	3.9	5.2	3.0	4.0	0.1	6.4	4.5
	13	4.7	3.4	5.6	2.9	4.0	4.4	7.0	3.5	2.8	0.3	5.6	5.0
	14	2.9	3.6	3.7	5.2	3.3	3.6	4.6	2.5	3.7	0.4	2.7	7.4
	15	2.4	5.7	5.0	3.0	5.6	4.9	5.6	6.3	2.9	0.4	6.2	6.5
	16	5.5	4.6	5.4	4.8	5.9	4.5	5.1	6.5	0.9	0.2	5.1	4.1
	17	4.9	4.0	3.0	3.0	5.2	4.3	5.2	4.5	3.5	0.3	3.5	5.0
	18	4.5	4.4	4.1	3.3	4.5	4.1	2.5	6.1	4.1	2.9	4.5	6.0
	19	2.8	4.1	4.5	5.8	4.5	4.4	4.6	6.9	5.2	0.2	4.0	5.8
	20	5.4	3.8	4.6	5.9	7.0	4.7	5.0	6.6	3.0	0.5	2.9	5.9
	21	3.9	3.9	9.4	4.4	5.3	2.2	6.0	3.2	1.0	0.7	2.0	4.8
	22	5.2	5.6	3.4	7.4	3.2	5.6	6.6	6.2	1.1	1.8	3.5	2.9
	23	4.0	4.6	2.4	5.3	3.2	4.2	3.4	5.7	2.1	0.6	8.0	3.1
	24	2.7	3.4	4.3	3.9	6.3	4.2	5.2	5.6	4.5	0.3	4.0	1.8
	25	4.7	3.8	3.6	7.5	6.6	4.6	6.0	5.5	3.0	1.3	4.0	4.0
	26	3.0	0.0	3.4	8.7	5.4	5.0	4.6	3.7	2.5	0.2	4.0	3.5
	27	7.8	0.0	5.1	6.1	5.0	4.0	4.2	2.0	5.0	0.4	6.3	3.0
	28	5.2	0.0	3.4	5.0	8.0	4.3	9.5	5.2	2.4	0.3	6.2	5.1
	29	6.4	0.0	7.0	7.6	3.5	3.7	4.5	5.6	1.2	0.2	3.5	2.8
	30	5.4	0.0	7.5	7.4	5.5	4.3	4.3	3.2	2.0	1.9	6.5	6.4
	31	5.5	0.0	3.5	7.1	4.0	3.0	4.3	5.0	5.8	0.4	8.9	3.3
	32	4.9	0.0	4.2	6.2	4.6	3.5	4.3	3.6	2.0	0.3	4.4	5.8
	33	2.9	0.0	4.5	9.2	6.0	5.5	7.3	4.6	3.1	0.2	6.3	7.6
	34	4.8	0.0	4.7	4.5	6.1	4.0	4.3	2.5	4.2	0.5	6.5	6.2
	35	4.6	0.0	5.3	3.4	5.2	3.4	8.5	5.2	4.5	0.4	7.2	3.9
	36	3.7	0.0	2.4	8.7	4.0	3.7	4.0	4.5	2.1	1.1	4.3	4.4
	37	2.4	0.0	3.0	3.4	2.7	2.5	3.0	3.2	2.0	1.2	8.6	3.1
	38	2.7	0.0	5.5	6.7	4.5	4.6	3.4	3.0	0.7	1.3	4.3	3.8
	39	3.1	0.0	6.7	7.1	4.6	4.7	4.5	3.0	4.3	1.1	4.4	2.9
	40	4.3	0.0	2.8	5.6	7.2	3.4	5.5	5.1	2.1	0.8	5.4	6.3
	41	3.4	0.0	4.0	3.4	5.7	3.1	6.0	3.2	3.0	0.7	4.4	4.5
	42	2.9	0.0	3.7	6.2	6.4	3.9	4.5	2.5	3.0	0.2	4.7	5.9
	43	3.6	0.0	4.3	5.5	5.1	3.5	4.2	3.5	3.1	1.0	3.2	6.3
	44	4.7	0.0	3.5	5.8	5.0	3.6	5.3	3.2	3.1	0.5	8.1	3.8
	45	2.3	0.0	4.7	7.6	5.3	4.6	5.5	4.3	3.0	0.0	5.2	3.2
	46	3.3	0.0	3.7	4.6	4.6	3.0	3.3	2.5	2.9	0.0	3.2	5.0
	47	4.2	0.0	5.9	5.3	5.2	4.5	5.4	3.5	3.2	0.0	4.6	3.7
	48	3.7	0.0	3.5	2.6	5.6	4.4	6.7	5.7	1.0	0.0	6.3	4.2
	49	3.5	0.0	2.5	3.7	4.3	4.0	6.0	4.3	2.1	0.0	4.0	3.6
	50	3.5	0.0	0.0	2.5	5.2	4.6	4.5	5.0	0.0	0.0	4.3	3.0
	51	0.0	0.0	0.0	2.5	5.5	4.4	5.0	6.0	0.0	0.0	0.0	6.0
	52	0.0	0.0	0.0	2.4	6.0	4.5	5.5	4.6	0.0	0.0	0.0	4.4
	53	0.0	0.0	0.0	4.5	6.5	2.5	4.5	3.5	0.0	0.0	0.0	5.3
	54	0.0	0.0	0.0	3.4	2.5	3.1	3.0	2.5	0.0	0.0	0.0	4.3
	55	0.0	0.0	0.0	3.5	6.7	0.0	5.0	0.0	0.0	0.0	0.0	3.6
	56	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1
	57	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
	58	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
	59	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 4 - Root Details - Raw Results

		Early Growth				Peak Growth				Senescence			
Tray	**Item**	**Experiment 1 - Root Leachate**	**Experiment 2 - Shoot & Stem Leachate**	**Experiment 3 - Leaf Litter**	**Experiment 4 - Control**	**Experiment 1 - Root Leachate**	**Experiment 2 - Shoot & Stem Leachate**	**Experiment 3 - Leaf Litter**	**Experiment 4 - Control**	**Experiment 1 - Root Leachate**	**Experiment 2 - Shoot & Stem Leachate**	**Experiment 3 - Leaf Litter**	**Experiment 4 - Control**
Tray 2	**1**	0.5	2.2	4.6	4.2	5.5	5.9	7.6	5.0	1.8	0.1	6.0	3.6
	2	3.6	0.0	1.2	7.8	5.7	3.5	6.7	7.5	4.2	0.3	4.6	3.8
	3	3.6	1.2	1.3	5.6	7.0	6.0	4.6	5.5	3.3	0.5	3.0	3.2
	4	4.0	0.9	4.1	6.5	7.2	4.4	4.0	4.5	2.8	0.2	3.5	5.1
	5	3.1	0.9	2.4	3.8	6.3	5.5	5.6	3.6	1.9	0.5	6.3	3.4
	6	2.1	2.5	2.7	7.0	2.5	4.8	6.4	7.0	1.9	0.4	6.9	4.7
	7	3.3	3.3	2.7	5.5	3.7	6.0	6.6	6.0	2.1	0.6	4.8	5.2
	8	2.7	3.0	3.0	6.3	7.6	4.7	7.0	6.0	4.0	0.4	4.2	3.5
	9	4.0	3.1	3.1	5.9	6.9	3.2	7.2	5.4	1.3	3.4	3.0	3.7
	10	0.0	1.0	3.9	4.7	5.6	3.5	4.6	6.2	2.9	0.6	4.1	6.1
	11	1.9	1.2	2.9	7.4	3.8	3.7	2.5	7.3	2.8	0.3	4.5	6.2
	12	2.1	2.5	5.4	4.9	3.9	4.3	6.0	5.7	1.1	0.2	3.5	6.9
	13	2.8	2.8	2.6	5.3	3.5	3.5	3.2	4.5	1.8	0.1	5.5	5.2
	14	2.3	3.4	3.0	6.2	3.5	3.4	9.3	5.0	1.1	0.1	5.2	4.9
	15	4.1	5.1	5.4	5.1	6.2	5.2	3.6	6.6	1.2	0.2	6.0	5.2
	16	4.1	3.8	0.5	7.5	5.7	3.7	4.7	5.0	4.6	0.2	3.0	5.0
	17	1.4	0.9	7.4	9.1	4.4	5.6	6.7	4.6	2.0	0.3	4.6	3.0
	18	0.6	4.2	3.8	3.7	3.5	5.3	8.6	6.5	3.0	0.4	3.5	2.2
	19	0.0	4.7	3.0	8.6	6.0	4.1	3.5	4.6	3.6	0.6	2.4	2.4
	20	0.0	6.0	4.0	3.1	7.2	3.9	5.2	3.7	1.7	0.3	7.6	4.7
	21	0.0	6.4	5.2	4.9	8.0	5.5	7.4	4.0	3.5	0.2	5.6	5.6
	22	0.0	2.2	3.4	9.8	4.0	4.5	5.6	4.2	3.6	0.1	6.0	3.5
	23	0.0	3.5	2.4	3.8	4.0	5.6	5.1	5.4	3.9	0.2	4.6	4.4
	24	0.0	3.1	2.5	3.0	5.5	5.6	7.9	3.0	4.1	0.3	3.6	3.0
	25	0.0	2.9	0.0	7.3	3.6	4.2	6.1	4.0	2.1	0.2	6.4	7.4
	26	0.0	2.8	3.4	10.6	3.0	4.2	7.5	4.9	1.1	0.2	5.8	3.6
	27	0.0	2.2	3.2	5.8	5.6	4.7	5.1	3.5	4.1	0.4	4.1	4.5
	28	0.0	2.9	3.3	6.3	3.2	5.1	6.5	4.0	3.7	0.3	3.9	3.0
	29	0.0	3.0	3.1	8.9	2.7	6.6	6.7	5.6	4.0	0.1	3.8	4.1
	30	0.0	1.9	4.3	7.7	3.2	4.2	7.2	4.6	4.6	0.1	2.4	3.9
	31	0.0	1.8	2.4	4.8	3.2	3.7	3.5	5.0	3.1	0.4	4.6	2.8
	32	0.0	3.4	5.7	7.4	5.0	4.2	7.6	3.2	2.0	0.3	4.7	3.3
	33	0.0	3.3	5.6	4.5	4.5	3.5	5.7	3.5	3.1	0.5	4.5	5.7
	34	0.0	0.0	2.6	8.9	5.4	4.0	3.5	4.5	1.8	0.4	2.9	6.9
	35	0.0	0.0	3.9	4.6	5.4	4.3	6.4	5.2	0.0	0.3	3.5	2.9
	36	0.0	0.0	2.8	5.9	4.3	3.7	6.6	5.1	0.0	0.4	4.4	3.0
	37	0.0	0.0	4.7	5.8	6.1	4.2	5.5	5.5	0.0	0.3	6.5	6.6
	38	0.0	0.0	2.6	8.8	7.2	3.3	6.1	4.4	0.0	0.6	4.4	3.7
	39	0.0	0.0	5.2	7.2	5.3	3.5	4.7	5.4	0.0	0.4	2.0	5.2
	40	0.0	0.0	7.0	5.6	4.5	3.0	3.5	3.5	0.0	0.2	4.2	5.0
	41	0.0	0.0	3.6	8.3	4.1	5.0	5.2	8.6	0.0	0.6	7.0	5.9
	42	0.0	0.0	4.5	5.2	5.7	4.6	4.0	5.7	0.0	0.8	6.6	3.6
	43	0.0	0.0	3.0	6.2	5.5	4.2	5.7	3.1	0.0	1.9	4.6	5.5
	44	0.0	0.0	3.5	5.7	6.3	4.0	3.8	4.4	0.0	0.9	6.4	3.0
	45	0.0	0.0	4.0	5.4	5.6	5.3	6.5	4.2	0.0	0.4	4.1	5.5
	46	0.0	0.0	4.7	4.6	5.0	4.0	3.2	9.0	0.0	0.6	4.5	6.1
	47	0.0	0.0	3.6	9.1	4.0	4.5	5.2	4.6	0.0	0.0	3.9	4.5
	48	0.0	0.0	2.5	3.9	6.2	3.6	6.5	3.7	0.0	0.0	6.0	3.6
	49	0.0	0.0	3.4	5.7	4.7	4.0	5.5	4.6	0.0	0.0	0.0	3.0
	50	0.0	0.0	0.0	3.5	4.5	5.3	5.7	5.5	0.0	0.0	0.0	3.9
	51	0.0	0.0	0.0	7.6	6.1	3.7	6.5	3.2	0.0	0.0	0.0	5.8
	52	0.0	0.0	0.0	9.0	5.5	4.6	6.4	5.2	0.0	0.0	0.0	3.8
	53	0.0	0.0	0.0	6.1	3.3	3.2	3.6	4.5	0.0	0.0	0.0	4.0
	54	0.0	0.0	0.0	7.8	3.5	3.0	6.5	4.6	0.0	0.0	0.0	4.4
	55	0.0	0.0	0.0	5.4	4.5	3.3	6.0	6.0	0.0	0.0	0.0	4.1
	56	0.0	0.0	0.0	9.3	4.6	5.0	5.4	9.0	0.0	0.0	0.0	3.3
	57	0.0	0.0	0.0	0.0	2.5	5.8	0.0	3.7	0.0	0.0	0.0	3.9
	58	0.0	0.0	0.0	0.0	6.7	2.5	0.0	3.4	0.0	0.0	0.0	6.7
	59	0.0	0.0	0.0	0.0	5.0	0.0	0.0	6.2	0.0	0.0	0.0	5.0
	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0

Appendix 4 - Root Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 3	**1**	3.9	5.5	5.4	6.6	3.4	3.6	4.1	5.4	2.0	0.2	4.1	4.4
	2	0.0	0.4	3.0	6.8	4.0	3.6	6.2	3.7	1.8	0.3	5.9	5.0
	3	0.0	0.5	7.7	7.3	5.6	5.2	5.4	6.7	1.0	0.1	4.9	4.6
	4	0.0	6.3	5.7	3.4	7.2	3.2	5.5	4.2	1.1	0.4	3.0	3.6
	5	0.0	6.9	3.7	5.7	4.5	3.5	4.9	5.0	2.3	0.2	5.2	4.1
	6	0.0	2.2	6.5	4.4	5.0	3.5	3.1	4.5	1.9	0.2	4.2	6.0
	7	0.0	4.5	0.0	6.5	5.5	3.7	5.0	5.5	1.8	0.1	6.4	3.2
	8	0.0	1.4	0.0	6.6	4.5	4.6	5.6	3.5	2.6	0.5	6.0	2.9
	9	0.0	3.5	3.2	5.6	4.5	4.5	4.5	5.7	2.4	0.2	4.1	5.5
	10	0.0	0.0	3.8	3.1	1.7	4.5	7.5	4.1	2.3	0.1	3.8	3.0
	11	0.0	0.0	4.2	3.6	6.7	4.6	4.6	5.5	2.0	0.1	5.9	5.3
	12	0.0	0.0	3.4	5.9	7.2	3.0	7.1	3.0	1.9	0.2	5.0	3.7
	13	0.0	0.0	3.2	5.4	0.7	6.9	5.6	3.8	2.7	0.1	4.7	3.1
	14	0.0	0.0	5.0	4.7	5.2	2.5	4.0	4.5	2.5	0.3	7.2	5.3
	15	0.0	0.0	2.4	7.0	6.3	3.2	6.8	5.2	2.6	0.5	4.6	4.9
	16	0.0	0.0	4.0	7.1	5.5	4.6	3.2	3.5	2.0	0.6	4.0	3.1
	17	0.0	0.0	1.0	5.6	3.0	4.4	6.2	6.9	2.5	0.1	4.5	2.9
	18	0.0	0.0	2.1	4.0	6.4	4.6	4.5	5.8	1.9	0.2	5.8	2.0
	19	0.0	0.0	4.7	5.2	6.4	3.6	3.9	3.2	2.3	0.3	2.5	2.5
	20	0.0	0.0	4.5	4.7	4.1	3.6	4.4	4.7	2.1	0.3	2.9	3.2
	21	0.0	0.0	3.0	4.3	3.5	5.0	5.0	3.0	3.0	0.4	3.2	3.5
	22	0.0	0.0	4.7	3.6	3.4	2.9	5.7	2.5	2.9	0.1	4.4	5.7
	23	0.0	0.0	6.0	7.4	2.3	3.0	4.4	4.2	2.5	0.2	2.2	5.2
	24	0.0	0.0	0.4	9.9	2.0	2.4	6.1	3.4	1.1	0.4	3.6	5.6
	25	0.0	0.0	6.4	10.0	5.1	3.6	4.9	4.0	2.6	0.5	7.1	3.2
	26	0.0	0.0	2.0	7.0	3.4	3.2	6.0	4.9	1.2	0.1	2.6	5.6
	27	0.0	0.0	2.5	4.2	3.2	3.4	4.6	4.2	2.1	0.1	8.4	3.5
	28	0.0	0.0	2.7	4.7	4.0	4.5	3.9	3.6	2.0	0.1	6.2	5.4
	29	0.0	0.0	1.4	4.4	5.5	5.8	3.6	4.4	1.0	0.7	4.2	3.5
	30	0.0	0.0	3.3	8.3	4.0	3.4	4.4	4.7	1.1	0.2	3.1	5.9
	31	0.0	0.0	1.5	6.7	4.0	2.8	3.9	5.2	3.6	0.4	5.8	3.6
	32	0.0	0.0	0.8	9.4	4.4	2.3	6.5	4.4	2.0	0.3	3.7	4.6
	33	0.0	0.0	3.5	5.0	6.2	3.2	2.3	5.5	2.5	0.4	6.1	4.7
	34	0.0	0.0	3.2	4.5	3.5	4.5	5.1	5.2	4.7	0.1	5.6	3.0
	35	0.0	0.0	4.4	6.7	6.4	3.3	7.4	6.0	1.7	0.4	3.4	4.6
	36	0.0	0.0	5.1	5.7	3.4	4.6	5.0	5.2	0.9	0.2	9.5	5.2
	37	0.0	0.0	2.5	6.4	8.6	3.0	3.5	5.3	0.8	0.6	3.4	3.1
	38	0.0	0.0	2.5	4.9	5.5	3.9	3.1	5.9	4.6	0.7	10.1	5.9
	39	0.0	0.0	3.5	7.2	7.6	3.0	5.0	5.9	1.1	0.1	7.6	4.5
	40	0.0	0.0	2.9	8.2	4.2	3.6	6.5	6.9	2.4	0.1	5.9	4.0
	41	0.0	0.0	2.2	7.4	8.5	3.5	3.4	5.6	2.7	0.1	8.6	4.0
	42	0.0	0.0	3.0	6.5	8.5	3.2	5.4	5.9	3.7	0.2	6.3	7.0
	43	0.0	0.0	1.0	4.9	10.0	3.4	3.6	3.5	3.4	0.0	6.8	2.9
	44	0.0	0.0	0.0	4.5	5.6	5.2	8.0	3.6	4.1	0.0	8.1	6.9
	45	0.0	0.0	0.0	5.0	6.6	6.5	6.6	4.9	0.0	0.0	2.8	4.5
	46	0.0	0.0	0.0	4.3	6.5	4.3	9.2	4.5	0.0	0.0	5.9	5.4
	47	0.0	0.0	0.0	6.4	0.0	5.5	5.9	5.9	0.0	0.0	0.0	3.7
	48	0.0	0.0	0.0	3.7	0.0	4.0	2.4	4.7	0.0	0.0	0.0	5.9
	49	0.0	0.0	0.0	3.6	0.0	4.3	3.7	4.7	0.0	0.0	0.0	5.4
	50	0.0	0.0	0.0	7.7	0.0	4.1	6.4	3.5	0.0	0.0	0.0	6.3
	51	0.0	0.0	0.0	6.0	0.0	4.3	5.5	3.9	0.0	0.0	0.0	5.4
	52	0.0	0.0	0.0	5.5	0.0	0.0	6.4	5.4	0.0	0.0	0.0	5.2
	53	0.0	0.0	0.0	5.4	0.0	0.0	3.9	6.6	0.0	0.0	0.0	4.0
	54	0.0	0.0	0.0	3.2	0.0	0.0	6.6	7.6	0.0	0.0	0.0	3.9
	55	0.0	0.0	0.0	4.9	0.0	0.0	0.0	3.2	0.0	0.0	0.0	4.6
	56	0.0	0.0	0.0	8.7	0.0	0.0	0.0	4.2	0.0	0.0	0.0	2.6
	57	0.0	0.0	0.0	3.9	0.0	0.0	0.0	3.2	0.0	0.0	0.0	4.0
	58	0.0	0.0	0.0	4.9	0.0	0.0	0.0	4.9	0.0	0.0	0.0	3.5
	59	0.0	0.0	0.0	6.6	0.0	0.0	0.0	5.7	0.0	0.0	0.0	2.9
	60	0.0	0.0	0.0	5.2	0.0	0.0	0.0	5.2	0.0	0.0	0.0	3.2

Appendix 4 - Root Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 4	**1**	2.5	4.7	3.9	6.0	4.5	2.4	5.1	7.6	2.9	0.4	2.9	3.6
	2	0.0	2.4	4.4	5.2	5.5	4.5	3.9	3.9	2.6	1.2	4.9	4.8
	3	0.0	3.3	4.5	4.5	3.6	3.6	4.5	5.9	1.8	0.1	4.1	3.1
	4	0.0	1.0	3.7	8.4	6.2	2.8	6.2	4.6	2.2	0.3	4.0	5.2
	5	0.0	3.7	2.8	5.9	4.1	2.5	5.1	5.8	2.3	0.4	3.4	3.7
	6	0.0	2.0	3.0	5.2	5.5	4.6	4.4	9.0	2.0	0.6	3.4	6.0
	7	0.0	5.0	4.4	4.3	4.2	2.9	4.5	3.6	0.5	0.7	5.1	5.1
	8	0.0	1.0	3.0	4.9	3.2	4.7	3.3	4.3	2.4	0.3	3.0	6.0
	9	0.0	4.0	0.8	5.8	6.0	2.2	6.5	4.0	2.5	0.3	4.5	3.6
	10	0.0	3.4	3.8	4.2	6.0	3.1	9.4	5.4	0.8	0.4	4.7	4.9
	11	0.0	2.1	4.5	9.4	4.0	4.5	6.5	7.8	4.3	0.5	6.2	5.1
	12	0.0	3.2	4.2	11.0	5.0	6.6	7.4	3.4	2.0	0.4	4.5	6.4
	13	0.0	2.0	2.3	7.6	3.5	4.1	8.3	5.3	4.6	0.4	3.1	6.1
	14	0.0	1.8	3.9	4.6	4.0	4.4	6.5	5.5	4.0	0.6	5.8	3.1
	15	0.0	1.9	2.0	10.2	6.7	3.5	4.1	5.7	4.1	0.7	5.6	5.2
	16	0.0	2.8	7.6	7.9	5.0	5.1	5.4	4.0	2.4	0.1	5.3	3.5
	17	0.0	0.7	4.0	8.9	4.9	3.6	5.2	5.2	2.0	0.5	2.8	6.3
	18	0.0	1.1	5.0	5.2	3.3	3.0	5.4	5.1	0.5	0.6	5.5	3.7
	19	0.0	2.1	5.4	5.2	4.2	3.1	3.5	6.0	0.6	0.3	4.3	5.0
	20	0.0	0.0	3.0	3.9	4.5	4.5	4.9	3.9	2.0	1.9	4.5	3.4
	21	0.0	0.0	5.5	4.5	3.5	3.6	6.8	6.3	0.8	0.1	3.8	4.2
	22	0.0	0.0	4.5	9.7	4.3	3.9	4.1	5.5	2.1	1.8	6.3	2.9
	23	0.0	0.0	3.0	5.0	4.4	5.1	4.7	4.2	1.9	0.1	4.0	4.0
	24	0.0	0.0	5.7	4.9	4.3	2.6	5.4	7.1	1.1	1.1	4.5	4.3
	25	0.0	0.0	5.0	6.4	3.7	4.9	2.9	4.9	1.9	0.8	5.9	5.9
	26	0.0	0.0	2.5	7.0	5.7	3.1	4.6	7.2	4.5	0.4	4.4	5.6
	27	0.0	0.0	2.0	6.2	7.0	4.7	3.4	3.5	0.7	0.3	5.6	3.4
	28	0.0	0.0	3.2	7.7	5.3	5.2	5.0	4.9	4.2	0.5	1.9	3.1
	29	0.0	0.0	2.3	4.3	6.2	5.5	7.4	3.5	2.9	0.2	3.4	5.2
	30	0.0	0.0	3.0	5.5	6.6	4.1	3.3	6.6	2.0	2.3	4.0	3.7
	31	0.0	0.0	2.5	6.0	4.3	4.3	2.4	3.6	3.0	0.9	4.4	4.1
	32	0.0	0.0	3.3	8.4	5.7	5.7	6.4	3.5	2.5	0.8	4.5	3.4
	33	0.0	0.0	2.7	6.7	6.3	5.5	7.5	5.4	1.0	0.5	2.3	2.7
	34	0.0	0.0	4.0	5.6	5.7	4.0	6.3	4.0	2.0	0.7	3.7	5.6
	35	0.0	0.0	3.7	7.5	6.0	4.6	4.6	3.8	1.8	0.5	3.5	4.2
	36	0.0	0.0	4.5	5.0	8.0	5.5	3.3	5.4	3.9	1.2	5.9	5.7
	37	0.0	0.0	3.0	5.4	7.7	5.4	4.1	4.1	1.4	0.6	7.5	5.8
	38	0.0	0.0	5.3	7.8	3.5	4.2	8.5	4.3	5.1	0.7	4.0	7.5
	39	0.0	0.0	3.4	7.6	8.2	3.6	5.2	4.5	2.1	0.6	4.6	3.2
	40	0.0	0.0	4.0	8.7	5.8	3.9	3.4	6.9	1.0	0.3	4.3	3.1
	41	0.0	0.0	2.5	5.2	4.0	3.5	7.1	6.0	0.0	0.5	4.2	5.1
	42	0.0	0.0	0.5	6.3	4.2	5.4	4.4	4.9	0.0	2.1	4.5	1.7
	43	0.0	0.0	3.4	5.9	6.5	3.2	3.9	8.5	0.0	0.4	5.5	5.2
	44	0.0	0.0	3.0	5.5	3.3	3.6	3.4	4.3	0.0	0.1	5.7	6.6
	45	0.0	0.0	2.7	4.6	8.0	5.9	5.1	4.0	0.0	1.8	4.4	7.5
	46	0.0	0.0	4.0	9.4	7.3	3.8	4.2	6.4	0.0	0.5	5.1	3.4
	47	0.0	0.0	0.0	5.6	5.5	3.7	5.9	7.7	0.0	0.4	3.1	4.3
	48	0.0	0.0	0.0	8.2	7.6	4.2	6.2	3.6	0.0	1.3	4.6	4.7
	49	0.0	0.0	0.0	5.2	4.5	5.9	4.7	5.7	0.0	2.5	0.0	2.9
	50	0.0	0.0	0.0	7.8	4.0	5.6	5.1	4.9	0.0	1.0	0.0	3.7
	51	0.0	0.0	0.0	5.4	4.8	3.4	6.1	6.0	0.0	0.2	0.0	4.0
	52	0.0	0.0	0.0	10.9	7.0	4.3	5.0	4.0	0.0	0.0	0.0	5.1
	53	0.0	0.0	0.0	4.7	3.9	3.6	0.0	5.5	0.0	0.0	0.0	4.0
	54	0.0	0.0	0.0	4.9	5.7	3.3	0.0	3.2	0.0	0.0	0.0	5.9
	55	0.0	0.0	0.0	3.7	4.0	3.0	0.0	3.0	0.0	0.0	0.0	3.2
	56	0.0	0.0	0.0	7.4	4.5	4.5	0.0	0.0	0.0	0.0	0.0	6.8
	57	0.0	0.0	0.0	6.4	6.5	3.2	0.0	0.0	0.0	0.0	0.0	4.3
	58	0.0	0.0	0.0	9.0	6.7	4.3	0.0	0.0	0.0	0.0	0.0	4.3
	59	0.0	0.0	0.0	10.7	5.5	4.4	0.0	0.0	0.0	0.0	0.0	4.7
	60	0.0	0.0	0.0	0.0	5.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 4 - Root Details - Raw Results

Tray	Item	Early Growth: Experiment 1 - Root Leachate	Early Growth: Experiment 2 - Shoot & Stem Leachate	Early Growth: Experiment 3 - Leaf Litter	Early Growth: Experiment 4 - Control	Peak Growth: Experiment 1 - Root Leachate	Peak Growth: Experiment 2 - Shoot & Stem Leachate	Peak Growth: Experiment 3 - Leaf Litter	Peak Growth: Experiment 4 - Control	Senescence: Experiment 1 - Root Leachate	Senescence: Experiment 2 - Shoot & Stem Leachate	Senescence: Experiment 3 - Leaf Litter	Senescence: Experiment 4 - Control
Tray 5	**1**	3.2	2.8	6.3	6.1	6.4	3.7	4.9	3.5	2.9	0.1	2.6	4.4
	2	0.9	4.6	6.4	7.8	4.6	2.4	4.5	4.0	4.5	0.2	3.4	4.2
	3	4.4	2.8	1.3	8.4	6.9	4.6	4.2	4.0	4.1	0.5	1.9	5.7
	4	3.3	4.5	2.4	6.0	4.0	3.1	4.4	6.2	6.1	0.8	5.5	4.1
	5	2.9	3.5	6.6	10.9	3.2	4.5	5.9	3.4	7.5	0.8	5.5	6.3
	6	4.3	5.6	2.2	6.2	5.7	4.1	6.1	4.0	2.8	0.9	5.2	7.6
	7	4.0	5.5	4.0	5.2	3.4	2.6	7.2	4.0	4.0	0.1	6.3	2.5
	8	3.5	3.8	4.0	5.8	8.1	2.9	4.2	4.1	5.0	0.2	2.4	2.3
	9	3.3	0.8	2.7	4.5	4.2	3.6	8.4	4.7	6.9	0.9	4.5	4.6
	10	2.7	3.4	7.2	4.3	4.3	5.4	5.7	4.0	4.5	2.3	5.4	8.1
	11	3.6	4.7	3.7	9.3	4.1	3.8	4.5	5.4	3.0	0.4	2.4	2.9
	12	3.7	1.8	5.7	11.1	5.9	3.3	5.9	4.5	8.5	0.8	6.4	6.2
	13	1.0	5.4	5.2	7.8	4.4	4.7	5.1	4.5	5.5	0.7	7.0	3.3
	14	2.7	2.6	6.4	5.3	3.9	3.1	4.5	7.5	5.4	0.2	5.2	6.1
	15	3.5	2.9	4.0	4.7	5.9	4.9	3.3	4.4	2.5	0.3	4.8	3.4
	16	1.0	2.8	5.5	4.6	3.1	3.1	6.1	4.5	5.6	1.0	6.4	6.1
	17	1.5	4.2	4.7	9.8	4.6	4.7	4.2	5.7	7.0	0.3	4.3	5.0
	18	2.7	3.3	4.0	3.6	3.4	4.5	4.2	7.7	4.3	0.6	3.1	3.0
	19	2.3	0.0	3.5	5.6	4.6	5.6	9.4	6.5	4.9	0.8	8.8	4.9
	20	3.0	0.0	0.9	6.2	5.0	4.4	6.5	8.7	3.3	0.6	5.3	5.9
	21	2.0	0.0	4.2	5.7	6.6	3.9	4.1	9.0	5.4	0.8	5.1	5.1
	22	1.9	0.0	4.2	7.3	4.9	4.8	5.2	5.5	6.1	0.7	4.3	6.6
	23	0.0	0.0	3.5	9.3	6.5	3.8	5.3	7.4	6.5	0.4	4.3	3.1
	24	0.0	0.0	2.6	5.9	5.6	4.4	4.4	6.5	3.8	2.0	8.0	4.2
	25	0.0	0.0	4.2	6.7	4.4	3.6	3.2	5.5	4.3	0.4	6.2	6.0
	26	0.0	0.0	4.7	4.2	4.0	3.0	4.1	6.5	3.0	0.2	3.1	5.2
	27	0.0	0.0	3.3	7.1	4.5	2.9	7.5	5.7	3.7	0.5	4.2	7.5
	28	0.0	0.0	3.4	5.7	4.9	4.5	6.3	6.4	4.6	0.4	6.4	5.6
	29	0.0	0.0	3.4	6.2	5.7	4.6	4.0	4.4	4.4	2.1	7.1	3.2
	30	0.0	0.0	4.0	6.1	3.5	3.2	7.1	4.2	4.2	0.4	4.2	6.3
	31	0.0	0.0	3.0	4.9	4.9	4.0	4.5	3.5	4.7	0.8	3.3	3.4
	32	0.0	0.0	5.9	7.2	3.8	2.9	2.6	6.6	4.1	0.3	5.0	5.4
	33	0.0	0.0	3.0	3.7	4.5	5.0	3.1	6.2	4.2	0.4	4.5	5.0
	34	0.0	0.0	4.9	3.6	6.0	4.3	3.6	5.0	3.3	0.5	4.0	4.6
	35	0.0	0.0	5.4	9.0	4.0	4.5	7.5	5.0	4.7	0.7	5.9	5.7
	36	0.0	0.0	2.9	7.6	4.0	3.8	8.0	3.5	7.5	1.4	2.9	3.6
	37	0.0	0.0	4.0	5.6	3.1	4.8	5.2	4.6	5.6	1.3	4.4	2.9
	38	0.0	0.0	2.5	7.4	5.2	4.0	5.8	4.5	0.0	2.0	4.5	4.6
	39	0.0	0.0	4.0	5.1	3.7	5.7	7.1	6.0	0.0	0.3	5.9	3.1
	40	0.0	0.0	0.8	8.2	5.1	5.6	6.0	5.7	0.0	0.9	2.9	4.0
	41	0.0	0.0	0.0	4.7	4.6	3.5	4.6	4.5	0.0	2.2	5.1	4.3
	42	0.0	0.0	0.0	5.1	5.4	4.5	5.1	5.2	0.0	0.8	2.8	5.7
	43	0.0	0.0	0.0	4.2	6.2	4.2	3.9	6.4	0.0	0.6	3.4	2.6
	44	0.0	0.0	0.0	9.7	3.6	4.1	5.1	5.2	0.0	1.9	4.1	2.1
	45	0.0	0.0	0.0	5.7	4.4	2.4	5.0	4.3	0.0	2.0	6.8	2.8
	46	0.0	0.0	0.0	9.3	4.5	3.8	4.6	5.9	0.0	0.5	4.5	4.1
	47	0.0	0.0	0.0	6.3	3.3	3.9	9.4	4.3	0.0	0.6	4.2	3.8
	48	0.0	0.0	0.0	8.0	7.1	4.8	5.9	4.9	0.0	0.3	6.2	3.5
	49	0.0	0.0	0.0	7.6	2.5	5.1	7.6	4.3	0.0	0.4	2.8	3.4
	50	0.0	0.0	0.0	5.7	4.6	5.5	3.6	5.9	0.0	0.0	6.9	3.9
	51	0.0	0.0	0.0	4.9	5.6	3.9	0.0	6.1	0.0	0.0	3.8	5.1
	52	0.0	0.0	0.0	9.2	4.6	5.1	0.0	5.8	0.0	0.0	0.0	4.0
	53	0.0	0.0	0.0	7.8	4.9	4.5	0.0	4.7	0.0	0.0	0.0	4.1
	54	0.0	0.0	0.0	8.7	6.4	3.2	0.0	0.0	0.0	0.0	0.0	5.9
	55	0.0	0.0	0.0	8.2	4.4	5.0	0.0	0.0	0.0	0.0	0.0	3.1
	56	0.0	0.0	0.0	9.9	3.3	7.2	0.0	0.0	0.0	0.0	0.0	6.8
	57	0.0	0.0	0.0	5.2	5.5	4.6	0.0	0.0	0.0	0.0	0.0	3.9
	58	0.0	0.0	0.0	0.0	6.3	6.1	0.0	0.0	0.0	0.0	0.0	5.9
	59	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	60	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 5 - Chi Square Analysis

OBSERVED	Early Growth Germ	Early Growth Not Germ	Peak Growth Germ	Peak Growth Not Germ	Senescence Germ	Senescence Not Germ			
Root Leachate	92	208	280	20	204	96	R1	900	
Shoot/Stem Leachate	103	197	281	19	232	68	R2	900	
Leaf Litter	227	73	267	33	243	57	R3	900	
Control	291	9	282	18	294	6	R4	900	
Phase Totals	1,200	1,200	1,200	1,200	1,200	1,200		3600	Grand Total
Germ Totals	2,796	804	2,796	804	2,796	804			
								12960000	

EXPECTED	Early Growth Germ	Early Growth Not Germ	Peak Growth Germ	Peak Growth Not Germ	Senescence Germ	Senescence Not Germ
Root Leachate	233	67	233	67	233	67
Shoot/Stem Leachate	233	67	233	67	233	67
Leaf Litter	233	67	233	67	233	67
Control	233	67	233	67	233	67

CALCULATIONS	Early Growth Germ	Early Growth Not Germ	Peak Growth Germ	Peak Growth Not Germ	Senescence Germ	Senescence Not Germ
Root Leachate	216.10	95.58	7.89	110.45	4.12	8.76
Shoot/Stem Leachate	164.08	85.79	8.20	121.26	0.00	0.01
Leaf Litter	0.16	0.49	4.33	35.03	0.41	1.75
Control	11.56	373.78	8.51	133.39	12.66	620.17

Chi Square **2,024.49**
df **17.00**

Crit Chi Square, 0.05 **23.69**

Ho: Treatment, Growth Phase, and Germination are independent
Ha: Treatment, Growth Phase, and Germination are not independent

Reject Ho: Treatment, Growth Phase, and Germination are not independent

Appendix 6 - Descriptive Statistics:

Early Growth

		% Germination	Min	Max	Mean	Standard Deviation	Variance
Root	Exp 1 - Root Leachate	31%	0.00	7.80	1.09	1.82	3.30
	Exp 2 - Shoot & Stem Leachate	34%	0.00	7.10	1.11	1.79	3.20
	Exp 3 - Leaf Litter	76%	0.00	9.40	2.86	2.10	4.42
	Exp 4 - Control	97%	0.00	11.10	5.92	2.18	4.76
Shoot	Exp 1 - Root Leachate	31%	0.00	10.80	1.42	2.55	6.52
	Exp 2 - Shoot & Stem Leachate	34%	0.00	9.20	1.42	2.43	5.88
	Exp 3 - Leaf Litter	76%	0.00	9.90	3.65	2.88	8.27
	Exp 4 - Control	97%	0.00	11.20	7.39	1.97	3.90

Peak Standing Growth

		% Germination	Min	Max	Mean	Standard Deviation	Variance
Root	Exp 1 - Root Leachate	94%	0.00	7.20	3.91	1.36	1.86
	Exp 2 - Shoot & Stem Leachate	93%	0.00	10.00	4.66	1.86	3.45
	Exp 3 - Leaf Litter	89%	0.00	9.50	4.69	2.16	4.67
	Exp 4 - Control	94%	0.00	9.00	4.64	1.76	3.11
Shoot	Exp 1 - Root Leachate	94%	0.00	10.40	6.31	2.18	4.77
	Exp 2 - Shoot & Stem Leachate	93%	0.00	10.90	6.30	2.20	4.83
	Exp 3 - Leaf Litter	89%	0.00	12.60	6.97	3.13	9.82
	Exp 4 - Control	94%	0.00	10.20	5.61	1.92	3.69

Senescence

		% Germination	Min	Max	Mean	Standard Deviation	Variance
Root	Exp 1 - Root Leachate	68%	0.00	8.50	2.01	1.85	3.42
	Exp 2 - Shoot & Stem Leachate	77%	0.00	3.40	0.46	0.56	0.32
	Exp 3 - Leaf Litter	81%	0.00	10.10	3.90	2.34	5.50
	Exp 4 - Control	98%	0.00	8.30	4.42	1.46	2.12
Shoot	Exp 1 - Root Leachate	68%	0.00	10.40	3.31	2.75	7.56
	Exp 2 - Shoot & Stem Leachate	77%	0.00	9.50	3.86	2.51	6.29
	Exp 3 - Leaf Litter	81%	0.00	11.30	5.28	3.15	9.91
	Exp 4 - Control	98%	0.00	13.00	6.63	1.95	3.82